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RESEARCH ARTICLE

Response of sweet basil to different irrigation rates and some micronutrients

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Abstract

Water deficiency is the greatest problem facing the world nowadays. So, reducing the plant water requirements is a very strategic aim. This investigation aims to examine the effect of irrigation rates and various doses of micronutrients on vegetative growth, oil yield, and the composition of sweet basil (*Ocimum basilicum* L.). A field experiment was conducted in a new sandy reclaimed land for two seasons. Different irrigation rates [60, 80, and 100% from gross irrigation requirements (IRg)] were examined. The farm irrigation rate was used as an irrigation control. Also, different rates of either Iron (Fe) or Manganese (Mn) (100, 200, and 300 ppm) in addition to farm fertilization as control were investigated in combination with irrigation rates. The response of plants to irrigation and micronutrients were recorded as growth and oil yield parameters. Results proved that plants irrigated with 100% of IRg and 300ppm of either Fe or Mn were superior compared with untreated plants (regular farm irrigation rate and fertilization). The vegetative growth characteristics were improved as a result of 100% of IRg and 300ppm of either Fe or Mn compared with the control. Also, volatile oil yield and components were enhanced at the same treatments. While the highest percentage of volatile oil was obtained at 60% of IRg in combination with 300ppm of either Fe or Mn. The results reflect the Fe and Mn roles in the activation of the enzymes, which may help plants to overcome the deficiency of water in the newly reclaimed land.

Key Words: GLC; irrigation; micronutrient; *Ocimum*; volatile oil.

1. Introduction

Basil (*Ocimum basilicum* L.) is a member of aromatic and medicinal plants. Also, it is one of the Lamiaceae Family. Basil has important properties like hypoglycemic, lowering blood pressure, antispasmodic, lowering fever, body compatibilizer stressors, and supporting the body's natural activity and anti-inflammation (Darrah, 1988). All Ocimum species yielded essential oils which are responsible for their uses as antimicrobial, antioxidant, antifungal, and anti-inflammatory activities (Nahak *et al*., 2011). In a considerable number of countries around the world, basil can be employed as an alternative crop because of its importance in different issues such as medicinal, economic, industries, and nutrition (Simon *et al*., 1990; Carovic-Stanko *et al*., 2010; Alhasan *et al*., 2020). The main products of basil are dry leaves, flowers and its essential oil (Makri and Kintzios, 2007). Basil essential oil has high economic value as it contains phenylpropanoids such as eugenol, chavicol, and their derivates and important terpenoids such as monoterpene alcohol linalool, methyl cinnamate, and limonite (Simon *et al*., 1990; Juliani and Simon, 2002; Akbari *et al*., 2019). The market for basil oil is dominated by European and Egyptian production (Nahak *et al*., 2011). The basil essential oil is thought to be responsible for its antimicrobial, insecticidal,

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nematocidal, fungistatic, herbicidal, and antioxidant properties, and for the plant to be resilient to stress factors (Adiloğlu, 2021). Therefore, increasing the productivity of the basil plant from fresh herbs and the essential oil per unit area is highly recommended to meet the demand for human needs and exportation.

The water scarcity is one of the major problems that climate change can cause. Therefore, it is important to reduce the use of water by employing more efficient water management (Debaeke and Aboudrame, 2004) and (Jacobsen *et al*., 2012). Better water management can contribute to maintaining agricultural sustainability and can be achieved by understanding the water needs of the different species as well as the water needs of the different cultivars (Debaeke and Aboudrame.2004). Also, irrigation water can be managed for high yield and for better quality by using tolerant cultivars to water stress (Blum, 2011). Anyway, the high irrigation levels significantly maximized the plant height, number of branches and fresh and dry weight/plant. While, the water deficiency associated with maximizing the moisture tension of the soil and lead to the reduction of growth parameters (plant height, branch number, number of leaves, fresh and dry weight) (Ibrahim *et al.*, 2021; Hamam *et al*., 2021).

On the other hand, the micronutrients are essential for plants, and the lack of the micronutrients leads to reduce crop productivity. The role of the micronutrients in alleviating water stress is not studied well. The micronutrients can activate certain physiological, biochemical, and metabolic processes under drought stress. The micronutrients may directly or indirectly affect the susceptibility of plants to stress factors via changing enzyme activity, modulating the signal transduction pathways, and/or producing some metabolites (Hajiboland, 2012).

Iron (Fe) has an essential and important role in numerous enzymes, especially enzymes related to or help in the respiration process, which includes catalase, peroxidase as well as cytochrome oxidase. In addition, Fe plays a direct role in the oxidation and reduction processes. The Fe participates in the processes of oxidation of these compounds, which is one of the important roles in cell metabolism operations. It is very critical in the chlorophyll synthesis and maintenance and the deficiency of Fe may lead to the appearance of yellow on the plant. It has a critical role in the respiration, nucleic acids, and chloroplasts (Nikolic and Kastori. 2000). Fe is involved in the production of chlorophyll pigment molecules. It is one of the essential components of numerous enzymes associated with the transfer of energy, nitrogen reduction, and fixation as well as lignin formation. In association with sulfur, iron forms compounds that catalyze other reactions in plants. Drought-induced deficiency of Fe causes chlorosis of leaves as a result of low levels of chlorophyll pigments content. Leaves chlorosis primary appears on the younger new upper leaves in interveinal tissues. Severe Fe deficiencies cause leaves to turn completely yellow or almost white which leads to their death. The uptake of Fe decreases with increasing soil pH. as well as high levels of available phosphorus. Also, soil contents of manganese and zinc also have adverse effects on Fe uptake (Waraich *et al*., 2011). Fe nutrition has an essential role in the protectivity of plants against oxidative stress resulting from drought (Abadia *et al.*, 1999).

Manganese (Mn) has an important role in the representation of nitrogen within the plant. Also, it activates numerous enzymes; like dehydrogenase and carboxylase. Mn is the central molecule of chlorophyll. The shortage of Mn affects chloroplasts, because of its important role in the fusion of water molecules during the photosynthesis process (El-Fouly *et al*., 2002; Piagentini *et al*., 2002). Mn is an important micronutrient that plays important role in plants. Also, it causes the activation of several enzymes of the tricarboxylic acid cycle and shikimic acid pathway leading to the biosynthetic pathway of isoprenoids and other secondary metabolites. Mn has an important role in keeping well balanced between both chlorophyll concentration and superoxide dismutase activity (Upadhyaya *et al*., 2012). Drought stress may cause deficiencies in Mn. This Mn shortage in dry soil results from inhibition of Mn conversion to suitable soluble forms (Hu and Schmidhalter. 2005).

So, this investigation aims to examine the effect of irrigation rates and various doses of micronutrients i.e., Iron and Manganese on sweet basil vegetative growth, oil yield and composition.

2. Materials and Methods

2.1. Plant source and culture

This study was implemented at the Experimental Farm of South Tahrir Horticulture Research Station, in Ali Mubarak Farm, EL-Bostan Area, Nubaria Region, El- Behira Governorate, Horticulture Research Institute (HRI), Agriculture Research Center, (ARC), Egypt, during the two successive seasons of 2019, and 2020. The seeds of sweet basil were obtained from the Medicinal and Aromatic Plants Research Farm, El-Kanater el-khairia, El-Kalubia Governorate, Egypt. The seeds of sweet basil were sown in the trays on February 15th, 2019, and 2020 in the first and second seasons, respectively. The seedlings of 15cm height with 3 pairs of leaves were transplanted in the experimental area at 25 cm apart on 1st April after 45 days from sowing. Sweet basil plants were harvested on June 15th representing the first cut and a second cut was taken on 15th September, for the 1st and 2nd seasons, respectively.

The physical and chemical characteristics of the soil of the experimental field were determined according to Jackson (1973) and are shown in Table (1). The experiment consisted of 28 treatments (4 irrigation rates x 7 nutrient elements).

Table 1. Physical and chemical analysis of the experimental soil.

Chemical and physical characteristics			Sandy soil	
			1st season	2nd season
Soluble Cations and Anions (mg./100g soil)	Soluble Cations	Ca^{+2}	0.64	0.65
		Mg^{+2}	0.30	0.32
		Na^{+}	0.38	0.41
		K^{+}	0.03	0.03
	Soluble Anions	CO3-	…….	…….
		$HCO3^{-}$	0.54	0.50
		Cl^{-}	0.38	0.39
		SO_4	0.40	0.40
	pH		8	7
	E.C. (ds/m)		0.26	0.26
	sand%		93	92
	Silt%		2.70	2.73
	Clay%		2.92	2.90
	Texture Class		Sandy	Sandy

2.2. The experimental design

The treatments were arranged in a factorial experiment, which included two factors; irrigation rates included four irrigation rates. The second factor was fertilization rates, which were four rates of Fe or Mn (100, 200, or 300ppm), in addition to the farm fertilization as a control. The split-plot design was used with three replicates. Irrigation levels were allocated at the main plots, while fertilization rates were at the sub-plots. The experimental plot was 3 x 8 m2 and contains nine irrigation lines. The drippers (with the discharge of four liters/hour) were spaced at 25 cm on the irrigation lines.

Irrigation treatments (main plots): Irrigation rates were calculated as a percentage of irrigation requirements (IRg) as the following:

2.2.1. Irrigation treatments (main plots)

Irr1: 60% of IRg (1200 and 1440 m^3/fed. in the first and second seasons, respectively),

Irr2: 80% of IRg (1600 and 1920 m^3/fed. in the first and second seasons, respectively),

Irr3: 100% of IRg (2000 and 2400 m^3/fed. in the first and second seasons, respectively),

Irr4: The farm irrigation implemented as a control (3200 and 3800 m^3/fed. in the first and second seasons, respectively).

Irrigation requirements were estimated according to the meteorological data of Ali Mubarak Experimental Farm, depending on Penman-Monteith equation. The data was collected from the Automated Weather Station allocated at the experimental site. The applied water was twice a week and the water irrigation requirements were calculated by following equation for two seasons of 2019 and 2020:

$$IRg = [(ET_o \times K_c \times Kr) / Ei] - R + LR$$

Where:

IRg = Gross irrigation requirements, mm/day,

ET_o = Reference evapotranspiration, mm/day,

K_c = Crop factor (FAO, 2002).

Kr = Ground cover reduction factor and the values of Kr measured by Keller equation as the following:

$$Kr = GC\% + 0.15 (1 – GC \%)$$

Where

GC% (Ground Cover) = The shaded area per plant/area per plant

Ei is the irrigation efficiency

R = Water received by the plant from sources other than irrigation in mm (for example rainfall)

LR = Amount of water required for the leaching of salts in mm

2.2.2. Fe and Mn treatment (sub-plots)

2.2.2.1. Foliar sprays distribution

Different rates of Fe and Mn (foliar sprays) were sprayed on plants four times during the both seasons as the following:

The first and the second does were sprayed after 30 and 45 days from planting.

The third one was after one week from the first cut.

The fourth spray was implemented after 15 days from the third spray.

2.2.2.2. The rates of Fe and Mn

Fe and Mn were obtained as commercial products containing chelated 12% of Fe and 12% of Mn. The rates of Fe and Mn were as the following:

The farm nutrient fertilization was implemented as fertilizer control.

Fe was added at three doses 100, 200, and 300 ppm.

Mn was added at three doses 100, 200, and 300 ppm.

2.3. The estimated data

2.3.1. The vegetative growth parameters

Plant height (cm), branches number/plant, plant fresh and dry weights (g), leaves weight/plant (g), stem weight/plant (g), leave/stem ratio (by weight), fresh herb yield (Ton/fed.), root length (cm)**.**

2.3.2. Determination of essential oil

2.3.2.1. The extraction of the essential oil

The essential oil was extracted from fresh plants material by hydro-distillation. The Clevenger-collector type apparatus was used for oil extraction according to Furnis *et al*. (1989). The distilled essential oil was stored in dark airtight bottles at 4 °C until conduced the oil chemical analysis.

2.3.2.2. The volatile oil percentage

It was determined in fresh plants of the two cuts through the both seasons according to British Pharmacopoeia (2002).

2.3.2.3. The volatile oil yield/plant (cm) and the volatile oil yield/fed (L)

They were determined for the two cuts of the both seasons**.**

2.3.2.4. The volatile oil components

volatile oil samples of the 2nd cut during the 2nd season were subjected to gas-liquid chromatography (GLC) according to the methods of (Hoftman, 1967; Bunzen *et al*., 1969).

2.3.3. Chemical composition

The plant contents of Fe and Mn were determined in the digested samples by atomic absorption according to Chaman and Pratt (1961).

2.4. Statistical analysis

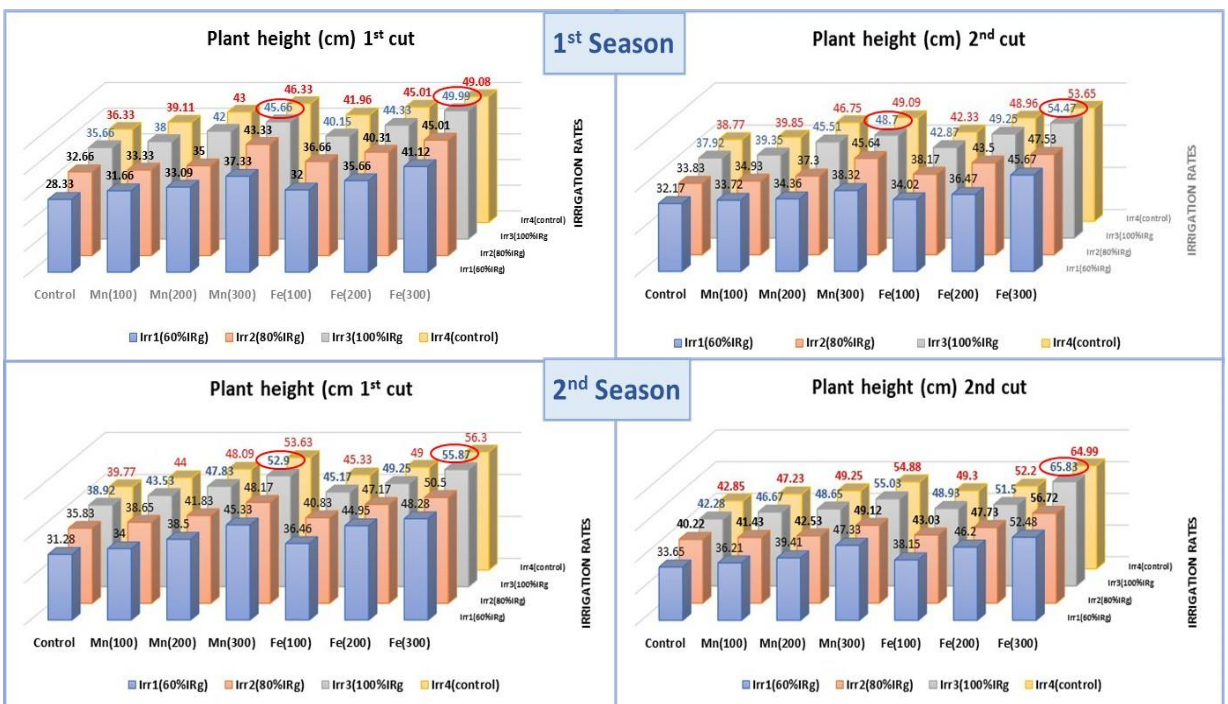
The experiment was arranged in a split-plot design with 28 treatments and three replicates. The statistical analysis was conducted using Co-stat software, 1085, according to Snedecor and Cochran (1980). The means of the treatments were compared using LSD at 5%.

3. Results and discussion

3.1. Response of sweet basil growth parameters to different irrigation rates and various doses of some Fe and Mn

3.1.1. Plant height

Data presented in Figure (1) showed the effect of irrigation management, and the rates of Fe and Mn on the plant height of basil plants. It could be noticed that increasing the rates of irrigation from 60% up to 100% of IRg in addition to control (irrigation with farm applied treatment) resulted in a significant increase in plant height in both cuts in the two seasons.



LSD (0.05)	1st Season				2nd Season			
Irr	1st cut	2.37	2nd cut	1.90	1st cut	2.86	2nd cut	3.02
T		1.75		1.49		2.45		2.25
IrrX T		3.25		2.99		5.15		4.77

Where: Irr1: Irrigation 60 %of IRg Irr2: Irrigation 80%of IRg Irr3: Irrigation 100 % of IRg Irr4: Farm irrigation

Figure 1. Response of sweet basil plant height to different irrigation rates and various doses of Fe and Mn through two seasons

However, 100% IRg and farm irrigation applied treatments showed the same effect with no significant difference between them. For the first season, the respective values at 100% IRg were 42.26 and 45.44cm in 1st and 2nd cut, respectively. Whereas, in the second season, the plant height values were 47.64, and 51.27 cm/plant for the first and the second cuts, respectively. The shortest plants (33.60, and 36.93cm) were recorded in those plants under 60% of IRg in the first season, and 39.83, and 41.92 cm/plant in the second season.

As for the effect of iron, it was noticed that spraying by Fe at 100, 200 or 300 ppm achieved significantly highest increases in basil plant heights. The tallest plants were 46.30, 50.33, 52.44 and 58.44cm with 300ppm of Fe, compared with the other treatments. Also, the addition of Mn at 100. 200, or 300 ppm had a significant effect on plant height of basil plants in the two cuts in both seasons compared with the control. The plants treated by Mn at 300ppm showed an increase of plant heights (43.16, 45.44cm) compared with the control (33.25, 35.67cm) in the 1st and 2nd cuts of the 1st season, respectively. The same results were observed in the 2nd season where the plant heights were 50.01, and 50.01cm at 300ppm Mn compared with 36.45, and 39.75cm for control of 1st and 2nd cut, respectively.

Concerning the effect of interaction between the irrigation rates and Mn or Fe doses on the plant height, it was clear from data in Figure (1) that there was a significant effect on the plant height. Plants which were irrigated with 100% of IRg and 300ppm of either Fe or Mn were superior compared with control (regular farm irrigation rate). In the first season, the highest plants were observed for plants which were irrigated with 100% of IRg and sprayed with either 300ppm Fe (49.99, 59.47cm) or 300 ppm Mn (45.66, 48.70cm) in the 1st and 2nd cut, respectively. The same trend was observed in the second season, where plants which were irrigated with 100% of IRg and sprayed with 300ppm Fe maximized the plant heights (55.87 and 65.83cm) as well as observed in the case of plants sprayed with 300ppm Mn (52.90 and 55.03cm), for the 1st and 2nd cut, respectively

3.1.2. Branches number/plant

Data in Table (2) indicated that increasing of irrigation rate from 60, 80, and100% of IRg as well as applied of farm irrigation significantly increased the number of branches/plant in both cuts through the both seasons. The maximum number of branches of the 1st and 2nd cuts of the first season (17.24, 20.11branch/plant, respectively) as well as the 1st and 2nd cuts of the second season (19.9, and 22.15branch/plant, respectively) were recorded in those plants which were irrigated at 100% IRg. However, there were no significant differences between 100% of IRg and farm irrigation rate.

On the other hand, results dealing with the effect of Fe and Mn rates on the number of branches/plant are presented in Table (2). Spraying plants with Fe and Mn at all rates (100, 200, and 300 ppm) significantly increased the number of branches compared with those of the control. The highest number of shoots was obtained in those plants sprayed with 300ppm Fe, the values were 19.76, 23.02branch/plant for 1st and 2nd cuts, respectively of the first season, and 21.93, and 23.58branch/plant for 1st and 2nd cuts, respectively of the second season. And followed by 300ppm Mn (18.25, 20.64branch/plant) for 1st and 2nd cuts, respectively of the first season, and (20.92, and 22.00 branch/plant) for 1st and 2nd cuts, respectively of the second season. The control in the two cuts of the both seasons possessed the lowest number of branches (11.48, 12.87, 13.94, and 15.73branch/plant).

From the results of the effect of interaction between the different treatments cleared that there was a significant effect on the number of branches/plant.

The beneficial effect of Fe or Mn was found to be synergistic with increasing irrigation rates from 60 to 100% of IRg in addition to the quantity of water with farm irrigation applied. It was shown that 100% of IRg and applied of farm irrigation treatments interacted with the spraying of Fe. The application with Mn showed the same effect. The largest number of branches/plant (21.66, 25.90, 23.70, and 25.33branch/plant) were obtained when plants were irrigated at 100% of IRg and sprayed by 300ppm Fe followed by those plants treated by 300ppm Mn under the same irrigation rate (20.67, 22.23branch/plant) for 1st and 2nd cuts, respectively, of the first season and (22.03 and 24.67 branch/plant) for 1st and 2nd cuts, respectively, of the second seasons.

Table 2. Response of number of branched of sweet basil to different irrigation rates and various doses of Fe and Mn through two seasons

Irrigation rates (m^3/Fed.)(A) / Fe & Mn rates (ppm)		First season, Number of branches/plant: First cut Irr1	Irr2	Irr3	Irr4	Mean	Second cut Irr1	Irr2	Irr3	Irr4	Mean
Control		9.34	10.57	12.67	13.33	11.48	10.33	12.66	14.00	14.50	12.87
Mn	100	11.47	13.61	15.67	16.84	14.40	11.67	13.33	17.94	17.33	15.07
	200	13.35	14.72	17.85	19.08	16.25	15.00	17.67	18.67	19.60	17.74
	300	15.27	16.67	20.67	20.37	18.25	18.33	20.00	22.23	22.00	20.64
Fe	100	12.23	14.95	16.70	16.00	14.97	13.33	18.00	20.33	20.23	17.97
	200	13.51	15.16	20.33	18.33	16.83	16.70	20.66	22.67	22.30	20.58
	300	17.09	18.30	21.66	22.00	19.76	19.66	21.66	24.90	25.86	23.02
Mean		13.18	14.85	17.94	17.99		15.00	17.71	20.11	20.26	
LSD (0.05)											
Irr				1.36					1.46		
T				1.30					1.05		
I rr X T				3.51					2.09		

Irrigation rates(m^3/Fed.)(A) / Fe & Mn rates (ppm)(B)		Second season, Number of branches/plant: First cut Irr1	Irr2	Irr3	Irr4	Mean	Second cut Irr1	Irr2	Irr3	Irr4	Mean
Control		12.67	13.33	14.00	15.75	13.94	13.33	15.00	17.00	17.60	15.73
Mn	100	14.00	15.33	17.00	17.50	15.96	16.33	17.33	20.23	20.83	18.68
	200	16.83	18.17	21.30	21.33	19.41	18.00	19.33	22.17	22.67	20.54
	300	18.50	20.83	22.03	22.33	20.92	19.00	20.33	24.67	24.00	22.00
Fe	100	15.00	17.33	19.40	19.17	17.73	16.33	19.83	21.97	22.33	20.12
	200	17.00	19.00	21.97	21.63	19.90	19.00	19.00	23.70	24.00	21.43
	300	18.67	21.00	23.70	24.33	21.93	20.30	22.67	25.33	26.00	23.58
Mean		16.10	17.86	19.91	20.29		17.47	19.07	22.15	22.49	
LSD (0.05)											
Irr				1.50					0.83		
T				1.00					1.20		
Irr X T				2.17					2.62		

Where: Irr_1: Irrigation 60 % of IRg Irr_2: Irrigation 80% of IRg Irr_3: Irrigation 100 % of IRg Irr_4: Farm irrigation.

3.1.3. Plant fresh and dry weight (g/plant)

The results in Tables (3) and Figure (2) showed that basil fresh and dry weight were considerably affected by irrigation rates, Mn and Fe application in both cuts during the two seasons. It could be noticed that, the highest fresh and dry weight/plant were recorded when sweet basil plants were irrigated at 100% of IRg, while the lowest values were recorded at 60% of IRg.

Spraying *Ocimum basilicum* plants by Fe or Mn at all rates significantly increased the fresh and dry weights per plant compared to the control. The highest fresh weight of the first season (203.39, 263.02g/plant) for the 1st and 2nd cuts, respectively and the highest fresh weight of the second season (245.88, and 289.79 g/plant) for the 1st and 2nd cuts, respectively were recorded with spraying Fe at 300 ppm. The same trend was observed in the case of dry weight, the highest dry weight for the 1st and 2nd cuts of the first season were 63.46 and 81.02g/plant, respectively and the highest dry weight for the 1st and 2nd cuts of the second season were 76.33, and 88.11 g/plant, respectively. Also, Mn at 300 ppm gave the maximum fresh weight for the 1st and 2nd cuts of the first season (182.97, 240.98g/plant, respectively). And 218.86, 253.06, g/plant fresh weight for the1st and 2nd cuts, respectively of the second season (Table, 3). Also, dry weights were maximized in the 1st and 2nd cuts of the first season (56.74, 74.64g/plant, respectively) as well as, in the 1st and 2nd cuts of the second season (67.73, and 78.68g/plant, respectively) when plants were sprayed with 300ppm Mn (Figure, 2). The results of the effects of the interaction between the irrigation and Fe or Mn on fresh and dry weights are presented in Tables (3) and Figure (2). There was a significant effect on the growth of plants in term of biomass (fresh and dry weight). The fresh weight recorded an increase when the plants were irrigated at 100% of IRg and sprayed by 300 ppm Fe, the recorded data in this concern were (243.99, 338.99g/plant) for 1st and 2nd cuts, respectively of the first season, as well as 297.74, and 365.17 g/plant) for the 1st and 2nd cuts, respectively of the second season. Spraying plants by 300 ppm Mn at 100% of IRg augmented the fresh weight (224.37, 308.58 g/plant) in the 1st and 2nd cuts, respectively of the first season, as well as in the 1st and 2nd cuts of the 2nd season (269.00, and 330.00g/plant, respectively) compared to all treatments. Also, data showed the same trend that was observed on the dry weight. Fe at 300 ppm with irrigation rate 100% of IRg gave the highest dry weights, followed by 300 ppm Mn with the same irrigation level, compared to all treatments.

3.1.4. Leaves and stem weight (g/plant) and leaves/ stem ratio

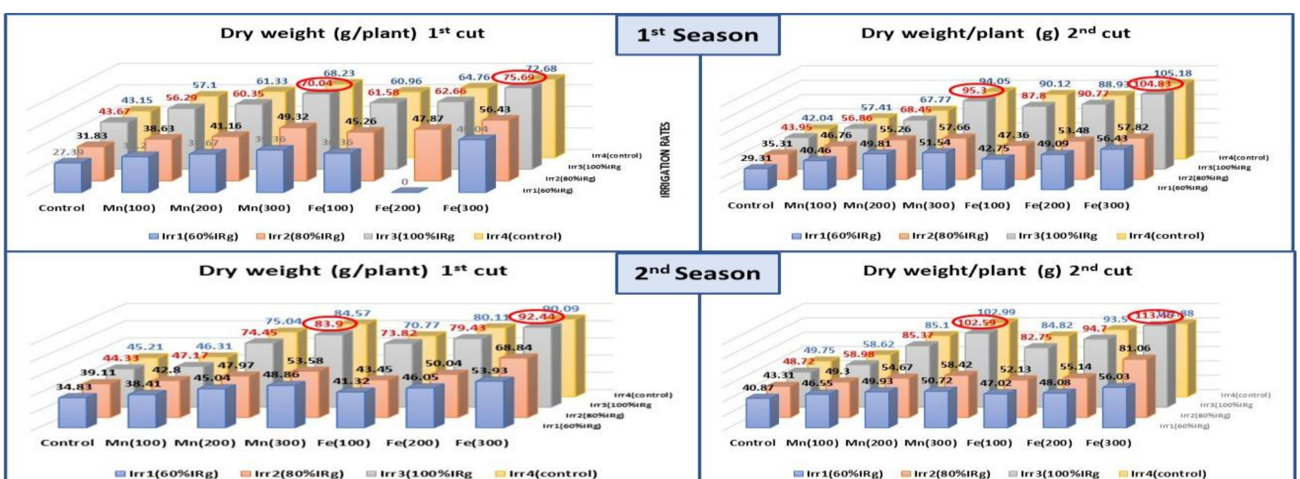
Data in Table (4) show that irrigation rates possessed a significant effect on leaves weights/plant, as previously observed in herb fresh and dry weights as a response of irrigation rates, as well as the spraying doses of Fe and Mn. Plants irrigated with 100% of IRg possessed the highest leaves weight/plant (131.50 and 171.16g/plant) for the 1st and 2nd cuts, respectively during first season, with no significant differences between 100% of IRg and farm regular irrigation. The same effects of irrigation rates were observed during the both cuts of the second season with general increase in all treatments. On the other hand, Fe at 300ppm showed significant superior effect on leaves weights (132.32 and 180.35g/plant) in 1st and 2nd cuts, respectively of the first season. Also, sprayed plants with 300ppm Mn gave a significant ascending in leaves weight (120.35 and 159.65g/plant) for 1st and 2nd cuts, respectively of the first season. Anyway, the second season gave the same response with general increase in the values of leaves weights/plants. Regarding the results of the interaction among treatments, in the 1st cut of the first season, Irr3(100 of IRg) combined with 300ppm Fe significantly maximized the leaves weight/plant (166.53g/plant) compared with Irr4 (regular farm irrigation) combined with 300ppm Fe (156.60g/plant) and Irr3 or Irr4 combined with 300ppm Mn (147.53 and 146.53, respectively).

Table 3. Response of sweet basil Fresh weight to different irrigation rates and various doses of Fe and Mn through two seasons

Irrigation rates (m^3/ Fed.)(A) / Fe & Mn rates (ppm) (B)		First season – Fresh weight (g/plant) – First cut Irr1	Irr2	Irr3	Irr4	Mean	Second cut Irr1	Irr2	Irr3	Irr4	Mean
Control		83.75	99.61	139.89	140.31	115.89	93.94	113.97	137.88	134.81	120.15
Mn	100	108.57	125.14	179.28	185.99	149.75	128.06	152.76	183.15	185.99	162.49
	200	113.33	130.75	193.07	198.94	159.02	157.90	179.49	221.38	219.46	194.56
	300	127.67	159.62	224.37	220.23	182.97	166.76	184.69	308.58	303.87	240.98
Fe	100	117.39	147.77	198.41	196.70	165.07	136.44	154.01	286.31	292.31	217.27
	200	134.86	150.45	202.56	209.75	174.41	157.60	173.96	290.98	287.61	227.54
	300	158.45	180.24	243.99	230.88	203.39	183.13	187.42	338.99	342.54	263.02
Mean		120.57	141.94	197.37	197.54		146.26	163.76	252.47	252.37	
LSD (0.05)											
Irr				3.43					1.00		
T				3.28					2.42		
Irr X T				7.11					5.24		

Irrigation rates (m^3/ Fed.)(A) / Fe & Mn rates (ppm) (B)		Second season – Fresh weight (g/plant) – First cut Irr1	Irr2	Irr3	Irr4	Mean	Second cut Irr1	Irr2	Irr3	Irr4	Mean
Control		112.66	126.14	144.38	145.74	132.23	131.78	139.96	156.65	159.90	147.07
Mn	100	127.48	138.64	150.80	151.61	142.13	151.08	171.34	189.74	188.95	175.28
	200	147.41	147.67	240.55	242.27	194.48	160.22	174.39	276.04	275.46	221.53
	300	158.84	173.25	269.00	274.35	218.86	165.29	187.23	330.00	329.72	253.06
Fe	100	136.80	136.38	237.29	217.89	182.09	147.90	169.17	267.24	282.97	216.82
	200	148.23	157.51	257.35	258.45	205.39	151.34	176.63	304.26	300.14	233.09
	300	175.25	221.54	297.74	289.00	245.88	179.01	260.62	365.17	354.25	289.76
Mean		143.81	157.30	228.16	225.62		155.23	182.76	269.87	270.20	
LSD (0.05)											
Irr				2.01					2.38		
T				2.90					2.90		
Irr X T				6.30					6.29		

Where: Irr1: Irrigation 60 % of IRg Irr2: Irrigation 80% of IRg Irr3: Irrigation 100 % of IRg Irr4: Farm irrigation.



LSD (0.05)	1st Season				2nd Season			
Irr	1st cut	2.00	2nd cut	1.00	1st cut	4.52	2nd cut	2.07
T		4.16		3.39		3.07		2.24
IrrX T		8.33		6.78		6.17		4.49

Where: Irr1: Irrigation 60 % of IRg Irr2: Irrigation 80% of IRg Irr3: Irrigation 100 % of IRg Irr4: Farm irrigation.

Figure 2. Response of sweet basil dry weight to different irrigation rates and various doses of Fe and Mn through two seasons

Table 4. Response of sweet basil leaves weight to different irrigation rates and various doses of Fe and Mn through two seasons

Irrigation rates (m3/Fed.)(A) / Fe & Mn rates (ppm) (B)		Leaves weight/plant (g) First cut Irrigation rats (m3/ Fed.) (I) Irr1	Irr2	Irr3	Irr4	Mean	Second cut Irrigation rats (m3/ Fed.) (I) Irr1	Irr2	Irr3	Irr4	Mean
Control		52.50	61.45	90.5	91.25	73.93	59.53	66.55	97.35	97.25	80.17
Mn	100	68.51	79.98	117.03	120.96	96.62	88.23	98.20	120.64	121.44	107.13
	200	73.00	85.51	128.06	131.5	104.52	103.26	116.73	146.59	145.57	128.04
	300	83.49	104.39	147.53	146.00	120.35	101.73	120.79	208.23	207.83	159.65
Fe	100	76.20	96.99	125.2	121.83	105.06	88.40	99.60	191.66	193.24	143.23
	200	87.04	101.11	145.66	145.30	119.78	121.13	126.33	198.31	196.87	160.66
	300	87.28	119.26	166.53	156.60	132.42	120.63	128.30	235.32	237.13	180.35
Mean		75.43	92.67	131.50	130.49		97.56	108.07	171.16	171.33	
LSD (0.05)											
Irr				1.17					2.65		
T				2.16					3.07		
I rr X T				4.70					6.66		

Irrigation rates (m3/Fed.)(A) / Fe & Mn rates (ppm) (B)		Leaves weight/plant (g) First cut Irrigation rats (m3/ Fed.) (I) Irr1	Irr2	Irr3	Irr4	Mean	Second cut Irrigation rats (m3/ Fed.) (I) Irr1	Irr2	Irr3	Irr4	Mean
Control		73.33	78.72	91.88	91.76	83.92	80.10	85.50	98.40	98.87	90.72
Mn	100	82.75	90.83	98.98	99.51	93.02	97.10	105.78	123.40	125.13	112.85
	200	96.58	97.44	158.17	158.73	127.73	99.07	108.83	182.53	183.33	143.44
	300	105.75	117.73	185.73	190.32	149.88	109.37	123.30	230.30	231.00	173.49
Fe	100	89.95	89.35	164.50	151.22	123.76	99.93	115.12	184.50	195.90	148.86
	200	98.10	104.00	178.32	178.15	139.64	102.90	119.55	215.82	200.87	159.79
	300	112.75	152.95	210.17	203.75	169.91	123.07	183.97	263.17	255.17	206.35
Mean		94.17	104.43	155.39	153.35		101.65	120.29	185.45	184.32	
LSD (0.05) :											
Irr				2.80					2.28		
T				2.05					1.80		
I rr X T				4.44					3.90		

Where: Irr_1: Irrigation 60 % of IRg Irr_2: Irrigation 80% of IRg Irr_3: Irrigation 100 % of IRg Irr_4: Farm irrigation.

The same results were observed for second cut of the first season as well as the both cuts of the second season.

Analyzed results of stem weight (Table, 5) revealed that both irrigation rates and fertilization doses affected stem weight/plant among all examined seasons. There were no significant differences between. Irr3 and Irr4 (64.55 and 67.47g/plant, respectively) in the 1st cut of the first season. The same result was observed for all other cuts. On the other hand, Fe and Mn rates positively affected stem weight. For 1st cut of the first season, Fe at 300ppm significantly maximized stem weight (65.33g/plant) compared with 300ppm Mn (62.62g/plant), the same trend was recorded for all cuts. As well as, the interaction results revealed that for the 1st cut of the first season, Irr3 in combination with both 300ppm of either Fe or Mn possessed the highest stem weights (77.46 and 76.84g/plant, respectively), with no significant differences between them and Irr4 (regular farm irrigation) and 300ppm of either Fe or Mn (77.23 and 74.23g/plant, respectively). The same results were observed for other cuts.

As well as, the results reflect the effects of both irrigation rates and foliar with Fe or Mn doses on leaves to stem ratio (Table, 6) indicated that leaves to stem ratio was significantly affected by both irrigation rates and foliar with Fe or Mn. There was a positive relationship between leaves/stem ratio and the increasing of irrigation rates. Anyway, the highest leaves/stem ratio obtained from 100% of IRg and Irr4 (regular farm irrigation) during both two cuts and two seasons with no significant differences among them. Also, spraying plants with different rates of Fe or Mn significantly enhanced leaves/stem ratio, 300ppm of either Fe or Mn significantly augmented the leaves/stem ratio (2.03 and 2.14, respectively, for 1st cuts and 2.16 and 2.01, respectively, for 2nd cut of the first season) compared with all other treatments all over the examined cuts and seasons. Finally, the interaction between irrigation rates and micronutrients levels proved that leaves/stem ratio was enhanced with increasing the irrigating levels as well as Fe and Mn levels. The highest leaves/stem ratio was recorded in those plants were irrigated by either Irr3 (100% IRg) or Irr4 (farm regular irrigation) combined with sprayed with 300 ppm Fe and followed the same irrigation rates with 300 ppm Mn, with no significant difference between these treatments, in both cuts for both 1st and 2nd seasons.

Table 5. Response of stem weight/plant of sweet basil to different irrigation rates and various doses Fe and Mn through two seasons

Irrigation rates(m3/Fed.)(A) / Fe & Mn rates (ppm) (B)		First season Stem weight/plant (g)									
		First cut					Second cut				
		Irr1	Irr2	Irr3	Irr4	Mean	Irr1	Irr2	Irr3	Irr4	Mean
Control		31.25	38.16	49.19	49.06	41.92	34.41	32.69	47.38	46.56	40.26
Mn	100	40.06	45.18	62.25	65.03	53.13	39.83	54.56	62.51	69.25	56.54
	200	40.33	45.24	65.01	67.44	54.51	54.64	62.76	74.79	73.89	66.52
	300	44.18	55.23	76.84	74.23	62.62	57.41	63.90	100.35	96.04	79.43
Fe	100	41.19	40.31	64.21	74.87	55.15	48.04	52.98	94.65	94.04	72.43
	200	47.82	49.34	56.90	64.45	54.63	49.87	54.41	92.67	90.74	71.92
	300	45.70	61.16	77.46	77.23	65.39	62.50	59.12	103.67	105.41	82.68
Mean		41.50	47.80	64.55	67.47		49.53	54.35	82.29	82.28	
LSD (0.05)											
Irr				2.28					2.22		
T				2.40					1.47		
Irr X T				5.22					3.19		

Irrigation rates(m3/Fed.)(A) / Fe & Mn rates (ppm) (B)		Second season Stem weight/plant (g)									
		First cut					Second cut				
		Irr1	Irr2	Irr3	Irr4	Mean	Irr1	Irr2	Irr3	Irr4	Mean
Control		39.33	47.42	52.50	53.98	48.31	51.68	54.46	58.23	61.03	56.35
Mn	100	44.73	47.81	51.82	52.10	49.12	53.65	58.77	66.34	63.82	60.65
	200	50.83	50.23	82.38	83.54	66.75	54.98	65.56	93.51	92.13	76.55
	300	53.09	55.52	83.27	84.03	68.98	55.92	63.93	99.70	98.72	79.57
Fe	100	46.85	50.78	72.79	66.62	59.26	48.04	54.05	82.74	87.07	67.98
	200	50.13	53.51	79.03	80.30	65.74	49.27	57.08	88.44	99.27	73.52
	300	56.66	68.59	87.57	85.25	74.52	55.94	76.65	102.00	99.68	83.57
Mean		48.80	53.41	72.77	72.26		52.78	61.50	84.42	85.96	
LSD (0.05)											
Irr				3.83					2.73		
T				2.38					1.16		
I rr X T				5.16					2.52		

Where: Irr_1: Irrigation 60 % IRg Irr_2: Irrigation 80% IRg Irr_3: Irrigation 100 % IRg Irr_4: Applied of farm irrigation

Table 6. Response of leaves/stem ratio of sweet basil to different irrigation rates and various doses of Fe and Mn through two seasons

Irrigation rates(m3/Fed.)(A) / Fe & Mn rates (ppm) (B)		First season Leaves/stem ratio First cut Irr1	Irr2	Irr3	Irr4	Mean	Second cut Irr1	Irr2	Irr3	Irr4	Mean
Control		1.68	1.61	1.84	1.86	1.75	1.73	1.88	1.91	1.96	1.87
Mn	100	1.71	1.77	1.88	1.85	1.80	1.72	1.80	1.93	1.89	1.84
	200	1.81	1.89	1.97	1.95	1.91	1.89	1.86	1.96	1.97	1.92
	300	1.89	2.12	2.26	2.27	2.14	1.90	1.90	2.07	2.16	2.01
Fe	100	1.85	1.91	1.95	1.93	1.91	1.84	1.88	1.91	1.90	1.88
	200	1.82	2.06	2.55	2.25	2.17	2.06	2.07	2.14	2.17	2.11
	300	1.91	1.95	2.15	2.11	2.03	1.93	2.17	2.27	2.25	2.16
Mean		1.81	1.90	2.09	2.03		1.87	1.94	2.03	2.04	
LSD (0.05)											
Irr				0.10					0.08		
T				0.10					0.06		
Irr X T				0.22					0.14		

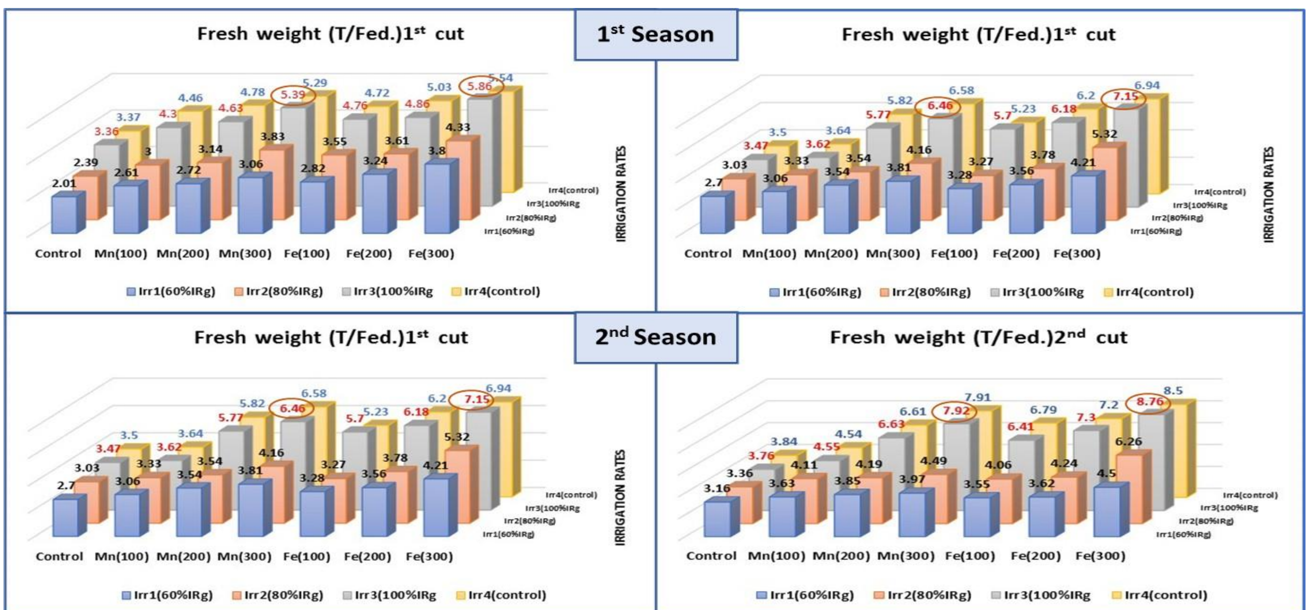
Irrigation rates (m3/Fed.)(A) / Fe & Mn rates (ppm) (B)		Second season Leaves/stem ratio First cut Irr1	Irr2	Irr3	Irr4	Mean	Second cut Irr1	Irr2	Irr3	Irr4	Mean
Control		1.67	1.66	1.75	1.70	1.70	1.55	1.57	1.69	1.62	1.61
Mn	100	1.85	1.90	1.91	1.91	1.89	1.81	1.80	1.86	1.96	1.86
	200	1.81	1.94	1.92	1.90	1.89	1.62	1.66	1.95	1.99	1.81
	300	1.99	2.12	2.23	2.27	2.15	1.96	1.93	2.31	2.34	2.14
Fe	100	1.92	2.17	2.26	2.27	2.16	2.08	2.13	2.23	2.25	2.17
	200	1.96	2.20	2.26	2.22	2.16	2.07	2.09	2.44	2.04	2.16
	300	1.99	2.23	2.40	2.40	2.26	2.20	2.40	2.58	2.56	2.44
Mean		1.88	2.03	2.10	2.10		1.90	1.94	2.15	2.11	
LSD (0.05)											
Irr				0.06					0.05		
T				0.07					0.07		
Irr X T				0.16					0.17		

Where: Irr_1: Irrigation 60 % of IRg Irr_2: Irrigation 80% of IRg Irr_3: Irrigation 100 % of IRg Irr_4: Farm irrigation

3.1.5. Fresh herb yield

Data concerning the yield of fresh herb as affected by irrigation rates and foliar application with concentrations of Fe and Mn are shown in Figure (3). It was noticed that the same trend previously recorded in the case of plant fresh weight was also obtained in fresh herb yield of basil in response to irrigation and trace elements and their interactions. The highest herb yield for the 1st and 2nd cuts of the first season (4.74 and 6.06 T/Fed., respectively) were recorded when sweet basil plants were irrigated at Irr3 (100% of IRg). Also, the highest herb yield for the 1st and 2nd cuts of the second season (5.48 and 6.48 T/Fed., respectively) were obtained at the same irrigation rate (Irr3), while the lowest values for the 1st and 2nd cut of the 1st season (2.89 and 3.51 T/Fed., respectively) and both cuts of the 2nd season (3.45 and 3.75 T/Fed., respectively) were recorded when plants were irrigated by Irr1 (60% of IRg). In the same way, spraying sweet basil with Fe or Mn significantly increased the herb yield/fed at all rates (100, 200, and 300ppm) compared to the untreated plants in both cuts during the both seasons. The treatment of 300 ppm Fe produced the highest values of fresh herb yield (4.88 and 6.31 T/Fed.) for 1st and 2nd cuts, respectively in the first season and (5.90 and 7.00 T/Fed) in 1st and 2nd cuts, respectively in the second examined season. Followed by Mn at 300 ppm, the herb yield values were 4.39 and 5.79 T/Fed. for the1st and 2nd cuts, respectively of the first season and 5.25 and 6.07 T/Fed. for the 1st and 2nd cuts, respectively of the second examined season.

The interaction between irrigation rates and micronutrients (Fe or Mn) cleared a significant effect of treated plants on the herb yield than the untreated plants. The highest yield was recorded in irrigated plants at Irr3 (100% of IRg) which were treated by 300ppm Fe. It produced 5.86 and 8.14 T/Fed. of herb yield in 1st and 2nd cuts, respectively of the first season. And 7.15 and 8.76 T/Fed. of herb yield in 1st and 2nd cuts, respectively in the second season. Followed by those plants under the same irrigation level (100% IRg) with 300ppm Mn, which produced 5.39 and 7.41 T/Fed of herb yield in the 1st and 2nd cuts, respectively, of the first season and 6.46 and 7.92 T/Fed. herb yield in both cuts, respectively in the second one. A considerable observation is the 2nd cuts of first and second seasons possessed high values of fresh herb weight (7.79 and 8.22T/Fed, respectively) when compared with the 1st cuts (7.41 and 8.14T/Fed., respectively) during first season as well as second season.



LSD (0.05)	1st Season 1st cut	1st Season 2nd cut	2nd Season 1st cut	2nd Season 2nd cut
Irr	0.42	0.55	0.42	0.47
T	0.64	0.89	0.64	0.71
IrrX T	1.19	1.56	1.19	1.52

Where: Irr_1: Irrigation 60 % of IRg Irr_2: Irrigation 80% of IRg Irr_3: Irrigation 100 % of IRg Irr_4: Farm irrigation.

Figure 3. Response of herb fresh weight of sweet basil to different irrigation rates and various doses of Fe and Mn through two seasons

3.1.6. Root length

Data presented in Table (7) illustrate that all the main root lengths showed a directly proportional relationship with irrigation rates. It was observed that increasing the irrigation rates from 60% up to 100% of IRg led to a gradual decrement in root length. Treating basil plants by Fe at high rates 200 and 300 ppm decreased the root length compared to those untreated or treated with low rates. On the other hand, treated basil plants by Mn at all rates tend to increase the root length.

In general, the irrigation rates and micronutrients (Fe and Mn) have significant effects on growth characteristics as, the plant height, number of shoots, fresh and dry weight, and fresh herb yield. The highest values of growth characteristics were obtained with irrigation rates Irr3 (100% of IRg) and sprayed with 300 ppm Fe followed by 300 ppm Mn at the same irrigation rate. While, the lowest values of growth characteristics in the first and second cuts in the both examined seasons were obtained with Irr1 (60% of IRg) regular farm fertilization (control) in the two cuts in both seasons. On the other hand, the root length decreased with increasing irrigation rates, as well as a foliar application by Fe and Mn. It could be concluded that the main root length increased with decreasing the rate of irrigation.

3.2. Response of sweet basil volatile oil to different irrigation rates and various doses of Fe and Mn

3.2.1. Volatile oil percentage

Data in Figure (4) showed a significant negative relationship between irrigation effects on the volatile oil of sweet basil plants. The highest values of volatile oil percentage(0.45 and 0.48%) for 1st and 2nd cuts, respectively of the first season and (0.47, and 0.49%) for the 1st and 2nd cuts, respectively of the second season were recorded in plants irrigated with Irr1 (60% of IRg) compared plants irrigated with Irr3 (100% of IRg) which produce low percentage of volatile oil (0.39 and 0.40%) for 1st and 2nd cuts, respectively of the first season and (0.38 and 0.39%) in the 1st and 2nd cuts, respectively in the second season.

The addition of Fe or Mn to sweet basil plants had a beneficial effect on volatile oil percentage. The highest values of essential oil percentage of sweet basil (0.49. 0.50, 0.48, and 0.51%) were recorded in those plants sprayed with 300ppm Fe during 1st and 2nd cuts of the first and second seasons, respectively. Followed by plants were sprayed 300ppm Mn which gave high volatile oil percentage (0.46, 0.46, 0.45, and 0.47%) during 1st and 2nd cuts of the first and second seasons, respectively. While, untreated plants produced the lowest volatile oil percentage (0.32, 0.32, 0.33, and 0.34%) during 1st and 2nd cuts of the first and second seasons, respectively (Figure, 4).

The results of interaction between irrigation rates and Fe or Mn doses were more effective on the volatile percentage of basil plants. The highest volatile oil percentages (0.53, 0.56, 0.55, and 0.57%) were recorded in basil plants irrigated with Irr1 (60% of IRg) combined with 300ppm Fe during 1st and 2nd cuts of the first and second seasons, respectively. while, plants were sprayed with 300ppm Mn with the same water irrigation rate (60% IRg) came in the second, no significant differences between them (0.52 and 0.55% for 1st and 2nd cuts of the first season, respectively and 0.54 and 0.55% for 1st and 2nd cuts of the second season, respectively). While, the control plants, especially regular farm fertilization, gave the lowest percentages of volatile oil (0.37and 0.36 for 1st and 2nd cuts of the first season, respectively and 0.37 and 0.39% for 1st and 2nd cuts of the second season, respectively).

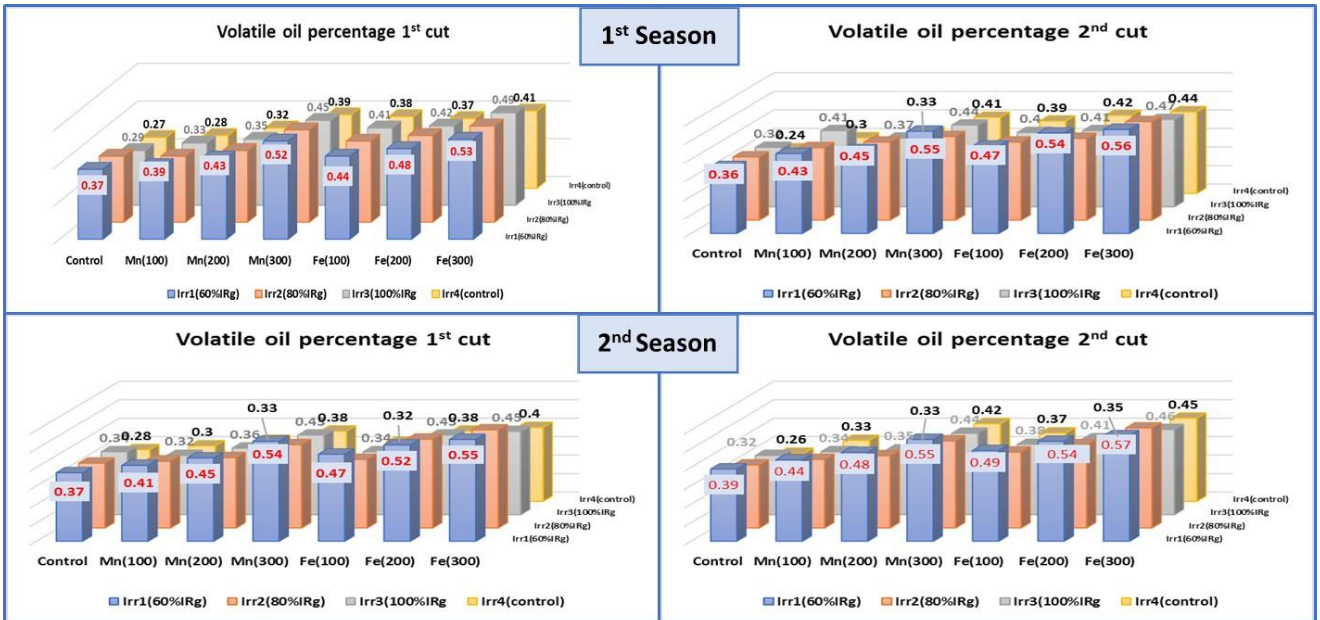
In general, it could be concluded that irrigation rates, and Fe and Mn play a significant role in the biosynthesis of the volatile oil in basil plants, so the highest oil content was obtained from plants irrigated with 60% IRg and sprayed by Fe and Mn at 300ppm.

Table 7. Response of sweet basil root length to different irrgation rates and various doses of Fe and Mn through two seasons

Irrigation rates (m3/Fed.)(A) / Fe & Mn rates (ppm) (B)		First season Root length (cm) First cut Irrigation rates (m3/ Fed) (I) Irr1	Irr2	Irr3	Irr4	Mean	Second cut Irrigation rates (m3/ Fed) (I) Irr1	Irr2	Irr3	Irr4	Mean
Control		15.09	14.39	13.32	12.58	13.85	18.73	18.08	17.20	15.29	17.33
Mn	100	15.58	14.72	13.50	13.25	14.26	22.76	20.47	18.00	18.70	19.98
	200	15.80	14.98	14.57	13.56	14.73	24.35	22.56	19.33	17.00	20.81
	300	15.85	15.72	13.62	13.76	14.74	25.75	23.08	20.93	18.67	22.11
Fe	100	15.72	14.32	13.86	13.27	14.29	19.30	18.00	18.33	16.00	17.91
	200	15.67	14.21	13.74	12.65	14.07	18.33	17.00	15.17	14.83	16.33
	300	14.92	13.89	13.65	11.55	13.50	17.33	16.65	14.83	14.50	15.83
Mean		15.52	14.60	13.75	12.95		16.43	17.68	19.41	20.74	
LSD (0.05)											
Irr				0.38					0.67		
T				0.15					0.49		
Irr X T				0.30					0.99		

Irrigation rates (m3/Fed.)(A) / Fe & Mn rates (ppm) (B)		Second season Root length (cm) First cut Irrigation rats (m3/ Fed) (I) Irr1	Irr2	Irr3	Irr4	Mean	Second cut Irrigation rats (m3/ Fed) (I) Irr1	Irr2	Irr3	Irr4	Mean
Control		18.63	16.60	13.55	13.67	15.61	19.80	18.96	16.50	15.70	17.74
Mn	100	18.70	17.97	14.17	12.85	15.92	21.93	20.56	18.19	17.50	19.55
	200	19.50	18.17	15.33	13.00	16.50	25.33	23.22	21.17	20.81	22.63
	300	19.67	18.83	16.00	14.60	17.28	28.35	26.15	23.11	22.63	25.06
Fe	100	18.50	17.90	14.17	13.90	16.12	22.08	20.44	18.33	16.20	19.26
	200	17.00	16.17	13.83	12.67	14.92	19.26	18.81	16.70	15.56	17.58
	300	16.30	14.53	12.17	12.45	13.86	17.97	16.37	14.35	14.53	15.81
Mean		18.33	17.17	14.17	13.31		22.10	20.64	18.34	17.56	
LSD (0.05)											
Irr				0.44					1.36		
T				0.48					1.87		
Irr X T				0.97					3.74		

Where: Irr_1: Irrigation 60 % of IRg Irr_2: Irrigation 80% IRg Irr_3: Irrigation 100 % of IRg Irr_4: Farm irrigation.



LSD (0.05)	1st Season 1st cut	1st Season 2nd cut	2nd Season 1st cut	2nd Season 2nd cut
Irr	0.010	0.031	0.017	0.030
T	0.020	0.019	0.015	0.020
IrrX T	0.041	0.040	0.030	0.039

Where: Irr_1: Irrigation 60 % IRg Irr_2: Irrigation 80% IRg Irr_3: Irrigation 100 % IRg Irr_4: Applied of farm irrigation.

Figure 4. Response of volatile oil % of sweet basil plant to different irrigation rates and various doses of Fe and Mn through two seasons

3.2.2. Volatile oil yield/plant and volatile oil/Fed.

Data recorded in Tables (8) and Figure (5) showed that the oil yield /plant, and the oil yield/Fed. were affected by irrigation rates, as well as Fe and Mn treatments. The highest volatile oil yield/plant a well as the highest volatile oil yield/Fed. were obtained from the plants were irrigated with 100%, of IRg, which ranged between 0.79 to 0.89ml/plant and 3.94 to 8.28L/Fed. for the first cuts during the two examined seasons. And for the second cuts of the both seasons, the volatile oil yield/plant and volatile oil yield per Fed. ranged between 1.00 to 1.05ml/plant and 5.59 to 7.40L/Fed. It can be concluded that 100% IRg is significantly superior in volatile oil yield when compared with the regular irrigation rate. On the other hand, the lowest volatile oil yield per plant and Fed. were observed in plants irrigated at 60% IRg for all cuts and all seasons (ranged between 0.31to 0.51ml/plant and 0.62 to 1.61 L/Fed.). These results showed that basil plants were stressed with the low irrigation. So, plants produced a low yield of volatile oil as the growth was found to be inhibited under low irrigation level. For these reasons, stressed basil plants produced the lowest yield of fresh herb and in turn less volatile oil yield (per plant and per Fed.).

Table 8. Response of Oil yield /plant of sweet basil to different irrigation rates and various doses of Fe and Mn through two seasons

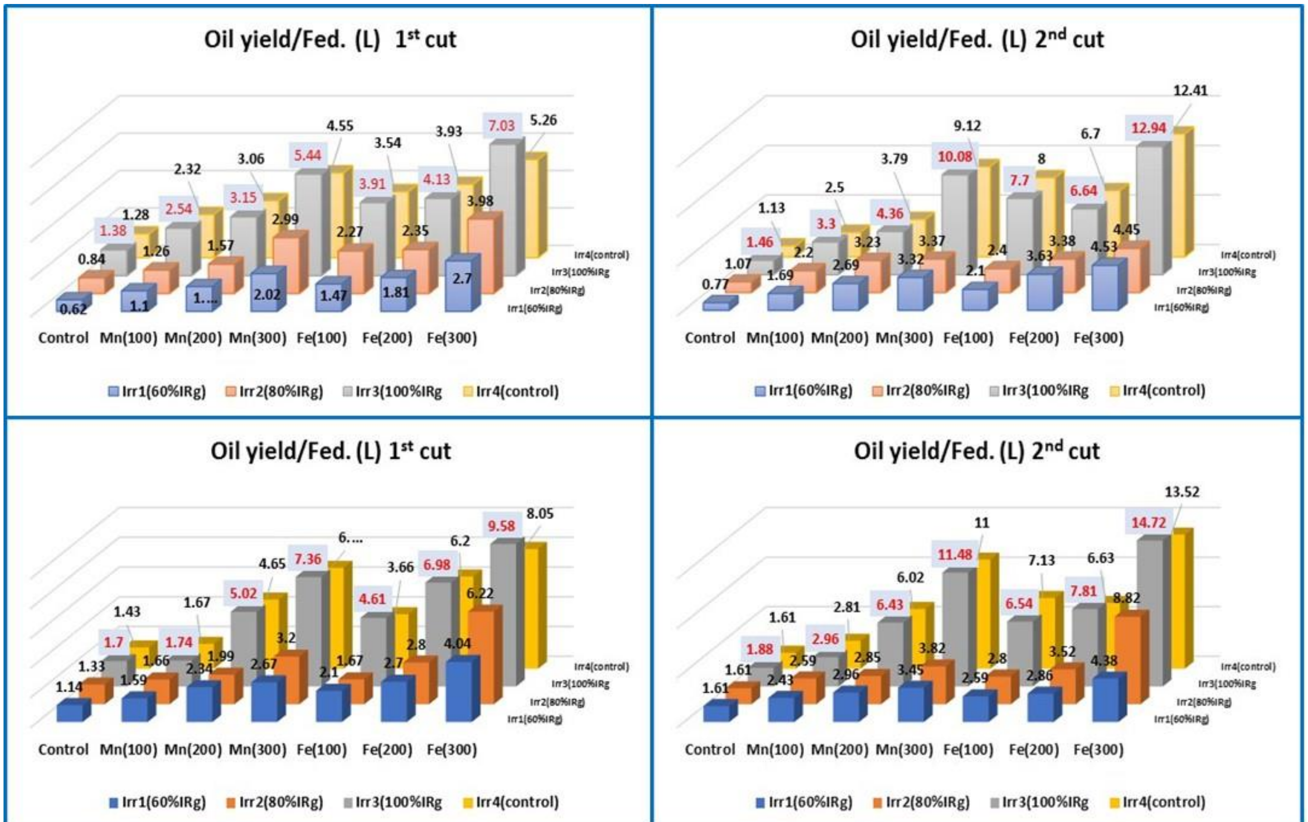
Irrigation rates (m3/Fed.)(A) / Fe & Mn rates (ppm) (B)		First season Volatile oil yield /plant (ml) First cut Irr1	Irr2	Irr3	Irr4	Mean	Second cut Irr1	Irr2	Irr3	Irr4	Mean
Control		0.31	0.35	0.41	0.38	0.36	0.34	0.39	0.44	0.35	0.38
Mn	100	0.42	0.44	0.59	0.52	0.49	0.55	0.60	0.75	0.56	0.62
	200	0.49	0.50	0.68	0.64	0.58	0.71	0.75	0.82	0.72	0.75
	300	0.66	0.78	1.01	0.86	0.83	0.83	0.76	1.36	1.25	1.05
Fe	100	0.52	0.64	0.82	0.75	0.68	0.64	0.65	1.12	1.14	0.89
	200	0.56	0.65	0.85	0.78	0.71	0.96	0.81	0.95	0.97	0.92
	300	0.71	0.92	1.20	0.95	0.95	1.03	0.99	1.59	1.51	1.28
Mean		0.52	0.61	0.79	0.70		0.72	0.71	1.00	0.93	
LSD (0.05)											
I				0.022					0.012		
T				0.038					0.022		
Irr X T				0.077					0.045		

Irrigation rates (m3/Fed.)(A) / Fe & Mn rates (ppm) (B)		Second season Volatile oil yield /plant(ml) First cut Irr1	Irr2	Irr3	Irr4	Mean	Second cut Irr1	Irr2	Irr3	Irr4	Mean
Control		0.42	0.44	0.49	0.41	0.44	0.51	0.48	0.50	0.42	0.48
Mn	100	0.52	0.50	0.48	0.46	0.49	0.67	0.63	0.65	0.62	0.64
	200	0.66	0.56	0.87	0.80	0.72	0.77	0.68	0.97	0.91	0.83
	300	0.70	0.77	1.14	1.03	0.91	0.87	0.85	1.45	1.39	1.14
Fe	100	0.64	0.51	0.81	0.70	0.67	0.73	0.69	1.02	1.05	0.87
	200	0.76	0.74	1.13	1.00	0.91	0.79	0.83	1.07	0.92	0.90
	300	0.96	1.17	1.34	1.16	1.16	1.02	1.41	1.68	1.59	1.43
Mean		0.67	0.67	0.89	0.79		0.77	0.80	1.05	0.99	
LSD (0.05)											
I				0.029					0.012		
T				0.028					0.022		
Irr X T				0.056					0.045		

Where: Irr_1: Irrigation 60 % IRg Irr_2: Irrigation 80% IRg Irr_3: Irrigation 100 % IRg Irr_4: Applied of farm irrigation.

As for Fe and Mn treatments, they have a significant effect in increasing volatile oil yield compared to untreated plants. The highest values of volatile oil yield per plant and volatile oil yield per Fed. were maximized at 300ppm Fe (ranged from 0.95 to 1.6 ml/plant and 4.74 to 6.97L/Fed. fror the 1st cuts of the both seasons), while the volatile oil yield of the second cuts of the two seasons ranged from 1.28 to 1.43ml/plant and 8.58 to 10.36L/Fed. Also, plants were sprayed with 300ppm Mn gave high volatile oil yield ranged from 1.05 to 1.14ml/pant and from 6.47 to 7.44L/Fed. for the 2nd cuts of both seasons.

The interaction between irrigation rates and Fe or Mn doses proved that volatile oil yield was significantly maximized compared with control when plants were watered with Irr3 (100% of IRg) plus 300ppm of either Fe or Mn. The highest values in this concern were 7.03, 12.41 L/Fed. for plants were treated with Irr3 and 300ppm Fe during 1st and 2nd cuts of first season, respectively. And 9.58, 14.72L/Fed. for the 1st and 2nd cuts of the second seasons, respectively. While, regular irrigation rate for the 1st and 2nd cuts of both examined seasons produced the lowest volatile oil yield which ranged from 0.62 to 1.61 L/Fed. for all experimental cuts.



LSD (0.05)	1st Season		2nd Season	
	1st cut	2nd cut	1st cut	2nd cut
Irr	0.39	0.62	0.27	1.08
T	0.54	0.93	0.49	1.68
IrrX T	1.04	1.56	0.98	2.16

Where: Irr_1: Irrigation 60 % IRg Irr_2: Irrigation 80% IRg Irr_3: Irrigation 100 % IRg Irr_4: Applied of farm irrigation

Figure 5. Response of Oil yield /Fed of sweet basil plant to different irrigation rates and various doses of Fe and Mn through two seasons

3.2.3. GLC analysis of volatile oil components

Data in Table (9) showed the GLC fractionated components analysis of the volatile oil of sweet basil plants of the second cut in the second season as affected by irrigation and microelements. It was clear that llinalool and methyle chavicol were the main components of sweet basil oil. Also, volatile oil contained α –Pinene, α –Myrcene, B–Pinene, Limonene, Camphor, Camphor, α –Terpineol, Fenchyl acetate, Eugenol, B-Caryophyllene. It was observed that linalool content was increased with increasing the irrigation level from 60 to 100% IRg. While, methyle chavicol decreased with increasing the irrigation level from 60 to 100% of IRg.

Concerning the effect of Fe and Mn doses on the different volatile oil components, it could be observed that the highest linalool content in sweet basil was observed in those plants sprayed by 300ppm Fe under both rates of irrigation 60 or100% of IRg followed by 300ppm Mn at the two rates. The opposite trend was observed, where Fe and Mn treatments decreased the methyle chavicol content under both irrigated levels compared to untreated plants.

Table 9. The main components of volatile oil of *Ocimum basilicum* plant according to GLC analysis

Treatments Compound	Irr1	Irr1Mn1	Irr1Mn3	Irr1Fe1	Irr1Fe3	Irr3	Irr3Mn1	Irr3Mn3	Irr3Fe1	Irr3Fe3
α –Pinene	0.56	1.02	1.53	1.20	2.47	0.99	1.35	1.89	1.95	2.85
α –Myrcene	3.19	3.32	6.60	5.70	7.35	4.90	6.45	6.95	6.65	7.98
B–Pinene	2.62	2.96	4.50	4.90	5.09	2.70	3.08	4.87	3.06	5.55
Limonene	5.33	6.08	6.90	6.65	7.20	5.65	6.55	7.20	6.95	7.86
Linalool	29.05	31.76	33.31	32.96	37.59	31.75	33.26	33.74	33.39	38.63
Camphor	7.55	7.45	7.90	8.09	8.44	6.70	7.90	8.25	8.45	8.85
α -Terpineol	4.06	5.09	5.24	5.23	3.56	4.43	5.33	5.97	5.65	5.90
Methyle chavicol	27.31	23.08	19.07	19.25	12.08	25.43	21.34	16.25	16.90	11.07
Fenchyl acetate	5.09	5.02	2.05	2.30	3.09	4.05	2.99	2.32	2.33	2.02
Eugenol	10.02	10.05	11.21	10.99	10.35	10.12	9.05	9.06	9.23	7.32
B-caryophyllene	0.07	0.09	0.60	1.09	1.06	0.70	0.51	0.35	0.03	0.06
Unknown	6.15	4.13	1.09	1.64	1.72	2.58	2.19	3.15	5.41	1.91

Where: Irr_1: Irrigation 60 % IRg Irr_3: Irrigation 100 % IRg Mn_1: 100ppm Mn_3: 300ppm Fe_1; 100ppm Fe_3: 300ppm

*The second cut plants of the second season were used for volatile oil extraction for GLC analysis.

3.3. Effect of different irrigation rates and various doses of micronutrients on basil plant content of Fe and Mn

Data in Table (10) showed the effect of irrigation rates and spraying with Fe and Mn doses on the concentrations of these elements in the leaves of the sweet basil plant. It was noticed that the concentrations of Fe and Mn in basil plants were affected by raising the irrigation rates. As for the concentration of Fe and Mn contents in basil plants it was found that Fe or Mn plant contents were increased with the foliar spraying with all rates of Fe and Mn compared to untreated plants in a gradual manner in response to foliar spraying with Fe and Mn. The highest Fe plant content (310.55ppm) was obtained at 80% IRg in combined with 300ppm Fe. While, the highest Mn plant content (28.293ppm) was obtained at 100% IRg and 300ppm Fe. It is known that there is a fateful role of water in nutrient elements uptake as well as transport and photosynthesis.

Table 10. Response of sweet basil iron and manganese content to different irrigation rates and various doses of Fe and Mn

Fe & Mn rates (ppm) (B)	Irrigation rates (m^3/Fed.)					
	Fe Content (ppm)			Mn Content (ppm)		
	Irr_1	Irr_2	Irr_3	Irr_1	Irr_2	Irr_3
Control	56.269	79.567	59.166	9.048	11.236	12.319
100ppm Mn	100.484	106.775	126.497	14.900	15.076	15.409
200ppm Mn	148.016	170.905	165.830	16.869	17.070	17.412
300ppm Mn	183.253	234.602	187.972	24.639	25.007	26.039
100ppm Fe	143.697	208.506	149.046	15.270	15.617	15.813
200ppm Fe	201.800	237.623	234.602	15.634	16.090	17.610
300ppm Fe	250.113	310.55	270.905	26.523	26.090	28.293

Where: Irr_1: Irrigation 60 % of IRg Irr_2: Irrigation 80% of IRg Irr_3: Irrigation 100 % of IRg Irr_4: Farm irrigation.

4. Discussions

The obtained results proved that irrigation rates as well as Fe and Mn foliar fertilization dose have significant effects on the basil growth characteristics, especially the plant height, number of shoots, fresh and dry weight, and fresh herb yield. Predominantly, the highest values of growth characteristics were obtained with irrigation rate 100% of IRg and sprayed with 300 ppm Fe, followed by 300 ppm Mn. While, the lowest values of growth characteristics in the first and second cuts in the both examined seasons were obtained with 60% of IRg without spraying of either Fe or Mn.

The fresh and dry weight decrements with low irrigation levels. This result may be due to the decrease in the water content ability of stressed plant cells and tissues, which lose their turgor and cells began shrink. So, these cells could not divide under stress. Also, these results may reflect the effects of Fe and Mn on cell metabolism or may be related to its essential role in the enzymes activation such as nitrogenase, catalase as well as peroxidase. Also, results may explain the Fe and Mn roles in respiration and photosynthesis through activation of the oxidation-reduction reactions. This increase may enhance the metabolism process and products as well as the cell osmatic which lead to increase the cell drought tolerance. The obtained results are in agreement with the finding of Amberger (1974), Marschner (1995), Marschner (1998) and El-Sawahly (2000) on *Borago officinalis*, Nikolic and Kastori (2000), Aziz and El-Sherbeny (2004) and Hendawy and Khalid (2005) on *Salvia officinalis*, Abd ElWahab (2008) on *Trachyspermum ammi*, Said-Al-Ahl and Omer (2009) on *Coriandrum sativum*, and Said-Al-Ahl and Mahmoud (2010) on *Ocimum basilicum*. They stated that increment in growth parameters as a result of spraying with Fe or Mn might be clear the effects of these microelements on plant metabolism as well as their vital roles in enzymes activity such as nitrogenase, catalase as well as peroxidase.

On the other hand, growth parameters possessed the highest values at 100% of IRg, while, the root length decreased with increasing irrigation levels, as well as a foliar application by Fe and Mn. Anyway, low values of growth parameters were recorded with decreasing the level of irrigation (60% of IRg), which may be related to the low ability of cell division during drought stress. These results were in accordance with the findings of Balasubramaniyan and Dharmatingam (1996), Schuppler *et al*. (1998), Reffat and Balbaa (2001), Kassem (2002), Hashem (2007), and Abd El-Wahab (2008) on soybean plants, thyme, rosemary, lemongrass, and *Trachyspermum ammi*, Ahmed and Mahmoud (2010), Rotaru (2011), D´Souza and Devaraj (2011), Garas (2011), Alvarez *et al*. (2013), Ibrahim *et al*. (2021) and Hammam *et al*. (2021). They reported that high irrigation levels significantly maximized the plant height, number of branches and fresh and dry weight/plant and concluded that water deficiency associated with maximizing the moisture tension of the soil and lead to the reduction of growth parameters (plant height, branch number, number of leaves, fresh and dry weight). Also, they conducted that results may reflect the effect of drought on the reduction of cyclin-dependent kinase activity which results in slower cell division as well as growth inhibition.

As well as, the main root length increased with decreasing the level of irrigation. Such significant increases in root growth in stressed plants may be attributed to the ability of roots to branch and elongate quickly to reach deeper levels in the soil to absorb more water. These results supporte the finding of Abdalla and El Khoshiban (2007), Ibrahim *et al*. (2021) and Hamam *et al*. (2021).

Concerning the volatile oil percentage and yield, irrigation rates and Fe and Mn fertilization played a significant role in the formation of volatile oil in plants. The low irrigation rate increased the volatile oil percentage. Also, the addition of Fe or Mn at 300ppm to basil plants enhanced the volatile oil percentage compared with untreated plants. the total yield was augmented with 100% of IRg in presence of 300ppm of either Fe or Mn. The results support the finding of Peka (1978) and Afify *et al.* (1993), Farahani *et al.* (2009), Abou-Dahab *et al.* (2010), Hammam *et al*. 2021 and Ibrahim *et al*. (2021). They stated that low irrigation levels significantly enhanced the oil percentage, while the oil yield/plant was maximized with the high irrigation rate. They explained the results as under drought stress more metabolites are produced in the plants and some substances prevent oxidization in the cells. So, under drought stress the volatile oil production in the most medicinal and aromatic plants was increased.

Also, results came in harmony with those obtained by Abd El-Wahab (2008) on *Trachspermum ammi* and Kalidasu *et al*. (2008) on *Coriandrum sativum*, Zehtab-Salmasi *et al*. (2008) on *Mentha piperita*, Nasiri *et al*. (2010) on *Matricaria chamomilla*, Said-Al-Ahl and Mahmoud (2010) on *Ocimum basilicum*, Younis *et al*. (2013) on *Rosa* hybrid, Ali *et al*. (2014) and Saleh *et al*. (2016). They estimated that spraying with either Fe or Mn gave the highest volatile oil yield. On the other side, components of the volatile oil were varied according to irrigation rates and Fe as well as Mn doses. llinalool and methyle chavicol were the main components of sweet basil oil. The highest linalool content was obtained in those plants sprayed by 300ppm Fe under both rates of irrigation; 60 or100% of IRg, followed by 300ppm Mn at the same rates. The opposite trend was observed, when Fe and Mn treatments decreased, the methyle chavicol content under both irrigated levels compared to untreated plants. Results supported the finding of Akbari *et al*. (2019), Mostafavi *et al*. (2019) and Alhasan *et al*. (2020) who reported that the components of volatile oils can be affected by irrigation, fertilization and genotypes. There is a fateful role of water and foliar spraying in nutrient elements uptake as well as transport and photosynthesis. Results recommended that the highest Fe content was obtained at 80% of IRg and sprayed with Fe at 300ppm., but the highest Mn content was obtained at 100% IRg plus Fe at 300ppm. These results refer to the roles of Fe and Mn on the growth process of the plant. The obtained results are in line with those obtained by Masinde *et al*. (2005), Pande *et al*. (2007) and Said-Al-Ahl and Omer (2009) on mint plant and *Coriandrum sativum* and Said *et al.* (2018) on the green bean plants. Where, they reported that Mn spraying on the plants augmented leaves content of Mn and Fe. Also, Abd El-Aziz (2000) on the basil plant and Eisa (2000) on fennel plant stated that spraying with Mn and Fe caused an increase in these microelements in the plant tissues.

5. Conclusion

Reducing the irrigation rate of sweet basil plants to 100% IRg (about 2000 to 2400 m^3/Fed.) in addition to spraying foliar (300ppm) of either Fe or Mn is the optimum treatment for maximizing growth parameters and volatile oil yield and components. On the other hand, reduction irrigation rate to 60% of IRg (1200 to 1440 m^3/fed) with 300ppm Fe or Mn enhanced the percentage of volatile oil, but the highest total volatile oil/Fed. was obtained from 100IRg with 330ppm Fe. Which means that sweet basil plants should be irrigated with 2000 to 2400 m^3/Fed. during the vegetative growth and flowering stage (stage of volatile oil formation and harvest).

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Ethics Approval and Consent to Participate

This work carried out at Medicinal and Aromatic plants Research department and Central Laboratory for Agricultural Climate and followed all the departments instructions.

Consent for Publication

Not applicable.

Conflicts of Interest

The authors declare no conflict of interest.

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