

Effect of Irrigation Scheduling and some Antitranspirants on Water Relations and Productivity of *Mentha viridis* L.

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Abstract: The current investigation was conducted during two successive seasons of 2017 and 2018 year to study the effect of different irrigation rate and some antitranspirants on growth, yield and some water relation of spearmint (*Mentha viridis* L.) under Middle Egypt (Fayoum region) conditions. The study involved three irrigation treatments; 100%, 80%, 60% IWR of irrigation water requirements and farmer application. Spraying by four antitranspirant substances (chitosan at 0.5%, liquid paraffin emulsion at 5%, aluminum silicate (kaolin) at 3g/l and titanium dioxide at 3g/l) was also studied. The obtained results proved that, irrigation water applied (IWA) and water consumptive use (WCU) were increased with the increase in the amount of irrigation, as farmer application treatment recorded maximum values of both while 60% IWA gave minimum values. The WCU differed due to antitranspirant, as non-sprayed plants consumed more water than the other antitranspirants and the lowest values were recorded with kaolin at 3g/l. The highest irrigation water productivity (IWP) was obtained from irrigation at 100% IWR, while the highest values of water use efficiency (WUE) for dry weight and oil yield were results from irrigation at 80% IWR comparable to the other tested %IWR treatments, as well as with liquid paraffin 5%, while the lowest values were recorded with farmer application as well as with non-sprayed plants for the both. Crop coefficient (kc) for spearmint crop was determined as average values of 0.65, 95 and 0.88 at the initial, mid-season and late stages, respectively. The maximum values of plant length, fresh and dry weight, leaf area index, carbohydrates, nitrogen, potassium and oil yield were results from irrigation at 100% IWR, while the maximum values of oil percent was obtained with irrigation at 80% IWR. On the other hand, all studied traits were significantly increased with liquid paraffin followed by chitosan while aluminum silicate had less effect in both seasons. The effect of interaction between irrigation treatment and antitranspirant was significant for all variables studied in the two seasons. The maximum values of the yield and its components were given by spraying the plants with 5% liquid paraffin emulsion at 100% IWR compared to the other antitranspirant tested. The best increase in carvone content shown at 100% IWR with liquid paraffin followed by chitosan, but limonene recorded an increase under farmer application with aluminum silicate and, conversely an increase of proline contents with irrigation at 60% IWR treatment. It can be stated that under Fayoum region, scheduling irrigation at 100% maximize yield and 80% IWR improve WUE of spearmint and allowed to save about 11.0 and 32.1% of IWA already being available to use in irrigating other additional lands.

Key words: Irrigation • Antitranspirant • Water use efficiency • Spearmint yield

INTRODUCTION

Irrigation management is one of the main inputs to ensure optimum productivity and crop quality in the agricultural sector. In arid regions like Egypt which is

characterized by limited water resources (its biggest share of Nile River is constant and minimal quantity of other recourse), agricultural production is limited by water rather than land availability. Consequently, the goal of strategies for sustaining agricultural production for

researchers is shifting from striving for maximum land productivity to striving for maximum water productivity. Implementing water management by scheduling irrigation according to weather factor to calculate irrigation water requirements (irrigation water added timely and sufficiently (with least losses) has become very important task under Egyptian conditions to increase water productivity and avoid the prevailing conditions of water scarcity. Spearmint crop is a high water use crop which led to irrigation practices in which water is applied frequently and in excess amounts, the application of some water shortage practices should be studied to determine the suitability of this method in raising the efficiency of the water unit and facing the challenge of water scarcity in Egypt. In this respect, many studies have shown that, deficit irrigation practices can lead to increased water productivity, not only in terms of output per volume of applied water, but in many cases crop quality and/or economic returns [1, 2]. However, deficit irrigation usually entails a risk of negative impacts to crop yield. Consequently, this has to be balanced against the benefits from the alternate uses for the saved water as well as an understanding of the yield and quality trade-offs. Enhancing plant resistance to drought stress would be the most economical strategy to sustain agricultural productivity in areas prone to water scarcity [3]. So merge a number of ways with some must be incorporated to saving water with the minimum negative effect is required. Stomatal control is the first and most important step in response to drought, as stomatal conductance reduces the rate of water loss and slows the rate of water stress development and minimizes its severity [4]. The potential for reducing transpirational water loss without significant reducing of photosynthetic rate is based on the premise that resistance to the movement of carbon dioxide in the mesophyll is greater than the stomatal resistance that limits water loss to the atmosphere [5]. Antitranspirants are natural or chemicals materials have been proposed to reduce water loss and enhance the water status of plant, it is grouped into three categories *i.e.* either a waxy compounds which form a waxy layer above the plant leaves surface and close stomata apparatus completely or partially (*i.e.* paraffin wax), or other compounds which control the movement of the stomata apparatus and prevent the full opening (*i.e.* chitosan). Where, chitosan may take a part in the Absciscic acid (ABA) biosynthesis, which plays an important part in response to environmental stress and altered the osmotic potential of stomatal cells causing them to shrink and stomata to close

[6]. The third type reflects the radiation of the leaves, reduce the temperature of the leaves and to reduce transpiration rate (Titanium dioxide, alumino silicate (Kaolin)). Later the first type is the most one applied in the field, including paraffin wax, emulsified oils [7].

Among many aromatic plants, spearmint (*Mentha viridis* L.) plays a crucial role, since international demand for spearmint essential oils increased in the past few years. It is one of the most important herbs traditionally produced in Egypt for hundreds of years.

The area cultivated with mint in 2019 exceeded 2622 feddan and produced about 6000 tons of herbs. Mint exports in this year were about 1250 tons, equal to 1.25\$ million (Ministry of Agriculture report - export sector; 2018). Spearmint (*Mentha viridis* L.) is a perennial crop cultivated for its leaves and essential, which are applicable in different sectors, such as food preservation, food confectionery and cosmetic industry [8-10]. It also used for its insect-repellent properties, antibacterial and antifungal activities and as antioxidant agent [11]. The main compounds responsible for these biological activities are carvone and limonene. Among the abiotic environmental stress factors, drought has the most important effect on medicinal plants [12]. Few studies have shown that spearmint biomass production is highly sensitive to water stress and it requires frequent and adequate irrigation supplies [7]. Behera *et al.* [13] examined irrigating mint at 100, 80 and 60% of pan evaporation (PE) in India and, stated that, the highest herbage (35, 798 kg ha⁻¹), oil yields (260 kg ha⁻¹) and 777mm water use were obtained at 100% PE.

The purpose of this investigation is to determine the responses of spearmint biomass yield, essential oil (quantity and quality) and water relation to irrigation regime and antitranspirants and their interactions under Middle Egypt condition.

MATERIALS AND METHODS

An experiment was conducted during two successive seasons of 2017 and 2018 years to examine the influence of water applied by irrigation, some foliar antitranspirants and their interactions in order to determine the appropriate rate of irrigation water requirements and the effectiveness type of anti-transpirant on water relation, water use efficiency, growth, yield, essential oil production and its composition of spearmint (*Mentha viridis* L.) under middle Egypt condition private farm at (Sinai farm, Fayoum region).

The study involved four irrigation treatments; I_1 farmer application, I_2 irrigating at 100% of irrigation water requirements (IWR), I_3 (80%IWR) and I_4 (60% IWR) under drip irrigation system, with spraying plants by four antitranspirants substances (chitosan at 0.5%, liquid paraffin oil emulsion at 5%, kaolin (alumino silicate, $(Al_2Si_2O_5(OH)_4)$ at 3g/l and titanium dioxide at 3g/l) compared to control (without antitranspirants), which laid out in a split - plot design with three replicates.

The plot area was 30m²(10x3m). The main plots were devoted to irrigation treatments and the sub plots were assigned to the antitranspirants. The antitranspirants were sprayed at 45 days then continuing periodically once every 15-day- intervals during the growing season of 2017 and 2018 years. Tween-80 at 0.03% as a wetting agent was used with the liquid paraffin and kaolin before spraying. All antitranspirants were sprayed with a fine mist using a hand pressure sprayer till run-off, with care being taken to cover all plant parts. The control plants were sprayed with water [14]. Chitosan at a concentration of 1 g L⁻¹ was dissolved in 0.01M acetic acid through gentle heating and continuous stirring then, pH was adjusted to 5.6 with 1 N sodium hydroxide (NaOH) [15]. Chitosan was added to the sub cultures of *Mentha varidis*. L at final concentrations of 0.5%. Titanium dioxide (TiO₂) film was prepared as suggested by Wynne [16] and Jiang, [17]. Titanium dioxide was added to the sub cultures of *Mentha varidis*. L at final concentrations of 5%.

Spearmint seedlings of 10-15 cm height were obtained from El-Kanater El-Khairia, Experimental Farm of Medicinal and Aromatic Plants Research Department, (ARC) and transplanted with the row width 0.70 m and the distance between plants was 0.3m in 2nd March, 2017 and 21th February, 2018 for the first and second seasons, respectively.

Chemical fertilizers, ammonium nitrate (33% N), calcium superphosphate (15.5% P₂O₅) and potassium sulfate (48% K₂O), were added at the recommended level as well as other cultural practices until the harvest date.

Irrigation was practiced using drip irrigation system and applied according to the cumulative values of the daily crop evapotranspiration (ET_c) calculated based on reference evapotranspiration (ET_o) using weather data of study site and was implemented from the second irrigation every four days interval during both growing seasons. The water flow-meter and a valve were used for each lateral line to control the amount of applied water for the different irrigation treatments with one dripper per plant of 4 liters per hour. Each irrigation treatment has one flow-meter to record the applied water.

Table 1: Soil characteristics of the experiment site

Soil properties	Value
1-Particles size distribution (%)	
Course sand	10.15
Fine sand	18.03
Silt	46.01
Clay	25.81
Texture class	Loam
2-Chemical properties	
EC dSm ⁻¹	3.35
pH 1:2.5 soil : water suspension	8.11
Soluble cations (mg L ⁻¹)	
Ca ⁺²	9.22
Mg ⁺²	5.21
Na ⁺	16.10
K ⁺	0.56
Soluble anions (mg L ⁻¹)	
CO ₃ ⁻	0.00
HCO ₃ ⁻	2.45
Cl ⁻	23.2
SO ₄ ⁻	4.18
O.M (%)	0.87

The soil samples were collected of the experimental site from consecutive depths of (0-15 till 60 cm depths) for physical and chemical analysis of the soil. The chemical properties of the soil samples; were determined according to the methods outlined by Page *et al.* [18]. Soil moisture content was gravimetrically determined, which field capacity was determined in the field, permanent wilting point by suing a pressure membrane apparatus and the bulk density using the core method to a depth of 60 cm [19]. Physical and chemical analyses of the soil are shown in Table (1) and soil water contents in Table (2).

Weather data used in the estimating reference evapotranspiration (ET_o) were collected from the Meteorological Station at El- Fayoum Region (Long.: 30.51, Lat.:29.18 and Elevation: 28.30 m) during the growing seasons and summered as shown in Table (3).

Plants were harvested on 31th May and 30th July, 2017 and 26th May and 28th July, 2018 respectively for all experimental unit and data collected recorded the following data measurements

Water Relations

Estimation of Irrigation Water Applied (IWA): The irrigation water requirements for spearmint plants during the both studied seasons; were calculated by computing the estimated reference evapotranspiration (ET_o) using Penman- Monteith equation included in "CROPWAT 8" model as per the standard procedure described in FAO 56 presented by Allen *et al.* [20].

Table 2: Soil moisture constants (% by weight) and bulk density (g/cm³) of soil for the experimental site

Depth, cm	Field capacity %	Wilting point %	Available water (mm)	Bulk density
00-15	33.10	16.93	33.47	1.38
15-30	32.81	16.91	32.91	1.39
30-45	32.67	16.90	32.64	1.39
45-60	32.31	16.88	31.94	1.39

Table 3: Some meteorological data at experimental site, 2017 and 2018 seasons

Season	2017							
Month	T min	T max	WS	RH	RF	SS	SR	Eto
February	8.3	21.5	173.0	54.0	5.1	11.0	19.4	3.6
March	12.0	25.1	199.0	47.0	1.3	11.9	23.8	4.8
April	15.1	28.4	207.0	41.0	0.1	12.7	27.5	6.1
May	19.2	34.4	173.0	34.0	0.0	13.4	29.8	7.2
June	22.0	36.5	173.0	33.0	0.0	13.9	30.8	7.9
July	24.9	38.0	138.0	42.0	0.0	13.8	30.4	7.5
August	24.6	37.1	173.0	46.0	0.0	13.1	28.4	6.2
Mean	18.0	31.6	177.0	42.4	6.5	12.8	27.2	6.2
2018								
February	9.4	19.9	156.0	58.0	2.1	10.5	16.2	3.2
March	11.1	22.1	130.0	47.3	0.9	11.5	22.9	4.5
April	12.4	28.0	121.0	44.0	1.1	11.8	23.6	5.6
May	15.3	29.1	138.0	42.0	0.0	12.9	27.2	7.1
June	21.2	34.8	164.0	36.8	0.0	13.5	29.2	8.2
July	25.9	36.1	181.0	38.9	0.0	13.8	28.5	7.8
August	24.0	37.3	164.0	45.0	0.0	13.6	28.5	7.4
Mean	17.0	29.6	150.6	44.6	4.1	12.5	25.2	6.3

where: T. max., T. min.=maximum and minimum temperatures °C; W.S= wind speed (km/ day); R.H.= relative humidity (%); R.F = rain full (mm/ month), SS = sunshine Hr, SR =solar radiation (Mj/m²/day) Eto= reference evapotranspiration (mm/day)

Then, crop evapotranspiration (ET_c) was calculated using FAO 56 crop coefficient.

Finally, Irrigation water applied was calculated according to Vermeiren and Jopling [21].

$$IWA = \frac{ET_{cxl}}{E_{ax}(1 - LR)}$$

where:

IWA = Irrigation water requirements (mm and m³/feddan).

ET_c = Crop evapotranspiration (mm day⁻¹).

I = irrigation intervals (days)

E_a = Irrigation application efficiency of the drip irrigation system (90%).

LR = Leaching requirements (assumed 10% from total irrigation water amount).

Water Consumptive Use (WCU): Water consumptive use was determined via soil samples from the sub plots just before each irrigation later as well as at harvest. Sampling depths were 15-cm successive layers up to 60-cm depth of the soil profile. The WCU was calculated according to Israelson and Hansen [22].

Then, the seasonal water use values were obtained from the sum of the WCU of all irrigations, from sowing until harvesting under different treatments for each cut under both growing seasons.

Irrigation Water Productivity (IWP): Irrigation water productivity (IWP) was calculated according to the following formula:

$$IWP = \frac{\text{Fresh weights yield (kg/fed)}}{\text{Water Irrigation Applied (m}^3\text{/fed)}}$$

Water Use Efficiency (WUE): Water use efficiency refers to (kg dry weight/ m³ of water consumed) was calculated according to Jensen [23] as follows:

$$WUE = \frac{\text{Dry weight yield (kg/fed)}}{\text{Seasonal WCU (m}^3\text{/fed)}} \quad (1)$$

Water use efficiency of oil yield (ml oil yield / m³ of water consumed) of spearmint was calculated according to Jensen [23] as follows:

$$WUE = \frac{\text{Oil yield (ml/fed)}}{\text{Seasonal WCU (m}^3\text{/fed)}} \quad (2)$$

Crop Coefficient (Kc Crop): The Kc crop was calculated from the general formula:

$$ET_{\text{crop}} = ET_o * Kc$$

where:

ET_{crop} = crop evapotranspiration (mm day⁻¹).

ET_o = Reference evapotranspiration (mm day⁻¹).

Kc = Crop coefficient.

Growth, Yield and Some Yield Attributes: At the end of each cut, six plants were taken at random to estimate the following characters: plant length (cm), herb fresh and dry weight (g/plant), leaf area index, essential oil percentage and essential oil yield (ml/plant).

Essential Oil Percentage and Constituents: Essential oil percentage was determined in the air dried herb according to the British Pharmacopeia [24]. The essential oil extracted in the second cut of the second season were subjected to gas-liquid chromatography (GC), as recommended by Hoftman [25] and Bunzen *et al.* [26].

The essential oil was analyzed using DsChrom 6200 Gas Chromatograph equipped with a flame ionization detector for separation of volatile oil constituents. The analysis conditions were as follows: The chromatograph apparatus was fitted with capillary column Bpx_5% polystyilphenylene_siloxane 30 mm x 0.25 mm ID x 0.25 µm film. Temperature program: Initial tem. Increase with a rate of °C/min from 70 to 80°C, rate of 5°C/min from 80 to 120°C and rate of 10°C /min from 120 to 190°C. Flow rates of gases were nitrogen at 1 ml/min, hydrogen at 30ml/min and 330 ml/min for air. Detector and injector temperatures were 300°C and 250°C, respectively. The obtained chromatogram and report of GC analysis for each sample were analyzed to calculate the percentage of main components of the essential oil.

Analytical Methods:

- Proline content in dry leaves was determined according to Bates *et al.* [27].
- Leaf Chlorophyll and carotenoids (mg/g FW) was determined in the third leaf of the plant tip (terminal leaflet) according to Lichtenthaler and Wellburn [28].

- Nitrogen % was determined in the digested solution according to A.O.A.C. [29]. While, potassium% was measured using flame photometer according to the method described by Kalra [30].
- Total carbohydrate: was determined according to Gul and Safdar [31].

Statistical Analysis: The Statistical analysis was done using MSTAT-C; the differences between the means of the different treatments were compared by using L.S.D test at 5% probability, according to Snedecor and Cochran [32].

RESULTS AND DISCUSSION

Water Relations Parameters

Seasonal Irrigation Water Applied (SIWA): Monthly irrigation water applied values are shown in Table 4 and Fig. 1. It started small at initial stage and lower temperature, then increased gradually to reached the maximum value with plant development and temperature increased (April to June), then, slightly declined was happened at maturity stage till harvest time and this funding was true in both seasons, except farmer application values, which continued increased until the second cut harvest time.

Seasonal irrigation water applied (IWA) values (Table 4 and Fig. 2) were gradually decreased as water stress increased; in the two cuts under both seasons and farmer application amount increased by 8.8 and 15.5% more than 100%IWR (ideal crop water needed). Overall seasonally IWA values were 5276, 4850 and 3880 and 3052 m³/ fed, for farmer application, 100%, 80% and 60% IWR in 2017, respectively. Corresponding values for 2018 season were; 5190, 4495, 3596 and 2868m³/ fed, respectively. On the other hand, cut two recorded high values of water amount more than cut one in 2018 season. This could be due to early planting in 2018, which reduces the water amounts in cut one, in addition to variation in weather parameter which, irrigation water requirement was calculated based on its (Table 1). These results are in harmony with those obtained by Behera *et al.* [13] who stated that irrigation at 100% PE required more water than the lower values of % PE on *Mentha arvensis* L. plants in India.

Seasonal Crop Water Consumptive Use (SWCU): In general, the seasonal WCU (sum of cut one and cut two) was higher during 2017 (769mm = 3235m³/fed) than 2018 (727mm = 3056m³/fed).

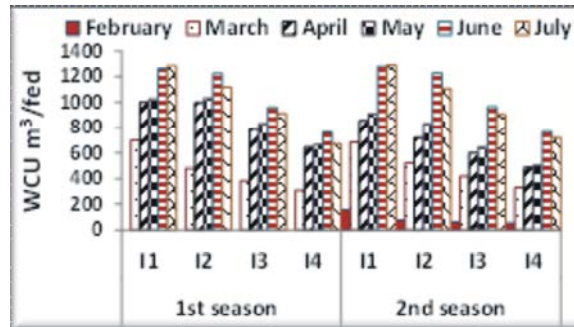


Fig. 1: Monthly water apply (m^3/fed) for spearmint affected by IWR rate (IWR %) in 2017 and 2018 season. where: I₁, I₂, I₃, I₄ ref to Farmer AP, 100%, 80% and 60% IWR

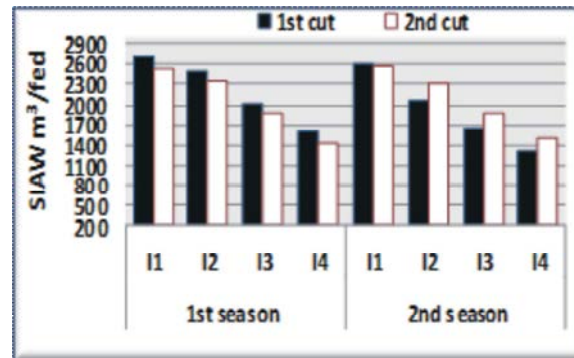


Fig. 2: Seasonal irrigation water apply (m^3/fed) for spearmint affected by (IWR %) in 2017 and 2018 season.

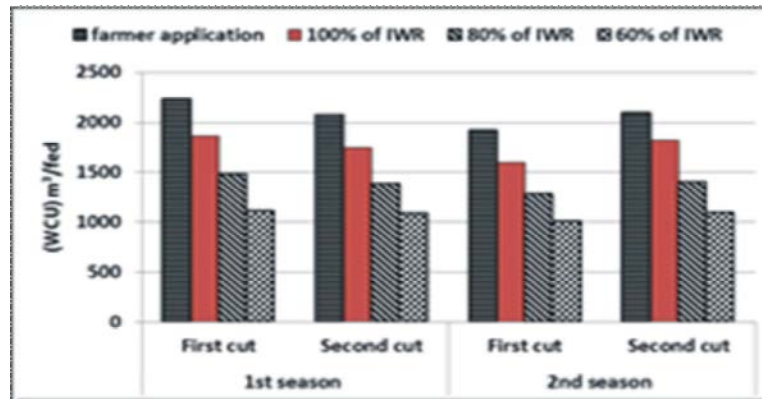


Fig. 3: Water consumptive use (WCU) m^3/fed for spearmint crop affected by (IWR %) for two cuts of 2017 and 2018.

Table 4: Seasonal and monthly water applied (m^3/fed) of spearmint plants in 2017 and 18 seasons

Season	2017				2018			
Months	Farmer Application	100% IWR	80% IWR	60% IWR	Farmer Application	100% IWR	80% IWR	60% IWR
February	-	-	-	-	158	76	61	49
March	699	480	384	310	686	523	419	334
April	1004	998	790	643	858	720	602	488
May	1026	1031	833	664	912	833	646	505
Total 1 st cut	2729	2509	2007	1617	2614	2152	1728	1376
June	1262	1224	959	764	1284	1231	965	769
July	1286	1118	914	671	1293	1104	903	723
Total 2 nd cut	2547	2342	1873	1435	2577	2335	1868	1492
Seasonal	5276	4850	3880	3052	5190	4487	3596	2868

IWR: Irrigation Water Requirement

Table 5: Seasonal water consumptive use (m³/fed) and Applied water use efficiency (kg FW/m³) of spearmint as affected

		Water consumptive use m ³ /fed						Applied water use efficiency kg FW/m ³ water					
		1 st season			2 nd season			1 st season			2 nd season		
		First cut	Second cut	Seasonal	First cut	Second cut	Seasonal	First cut	Second cut	Seasonal	First cut	Second cut	Seasonal
Irrigation Treatments		2228	2079	4306	1918	2093	4011	1.38	1.29	1.33	1.47	1.21	1.34
Farmer application		1867	1743	3610	1598	1828	3426	2.05	1.83	1.94	2.21	1.67	1.94
100% of IWR		1485	1386	2871	1278	1402	2681	1.96	1.92	1.94	2.14	1.62	1.88
80% of IWR		1107	1086	2154	1007	1089	2096	1.44	1.31	1.37	1.56	0.97	1.27
60% of IWR													
Overall average			3235			3056							
Antitranspirants													
Control (without spray)		1742	1578	3295	1475	1596	3071	1.22	1.13	1.17	1.43	0.97	1.20
Chitosan		1670	1575	3234	1443	1591	3034	1.94	1.80	1.87	2.07	1.52	1.80
Liquid paraffin		1691	1608	3273	1457	1660	3116	2.17	1.99	2.08	2.28	1.73	2.01
Kaolin 5 %		1613	1544	3153	1433	1580	3013	1.46	1.42	1.44	1.56	1.22	1.39
Titanium dioxide		1644	1563	3197	1445	1589	3033	1.74	1.60	1.67	1.88	1.38	1.63
Interaction: Irrigation X Antitranspirant													
Irrigation	Antitranspirant												
Farmer Application	Control	2380	2131	4511	1946	2111	4057	1.09	1.00	1.04	1.24	0.84	1.04
	Chitosan	2206	2088	4294	1908	2079	3987	1.57	1.48	1.53	1.57	1.41	1.49
	Liquid paraffin	2258	2103	4361	1925	2116	4041	1.72	1.57	1.64	1.80	1.61	1.70
	Kaolin 5 %	2128	2027	4155	1897	2074	3971	1.10	1.13	1.11	1.18	0.95	1.07
	Titanium dioxide	2167	2044	4211	1915	2083	3998	1.42	1.26	1.34	1.53	1.21	1.37
100% IWR	Control	1987	1773	3660	1629	1799	3428	1.55	1.37	1.46	1.72	1.30	1.51
	Chitosan	1851	1730	3581	1592	1784	3376	2.37	2.06	2.21	2.53	1.86	2.19
	Liquid paraffin	1860	1761	3621	1609	2003	3612	2.53	2.25	2.39	2.66	2.04	2.35
	Kaolin 5 %	1800	1711	3511	1575	1772	3347	1.66	1.66	1.66	1.83	1.56	1.69
	Titanium dioxide	1836	1740	3576	1587	1781	3368	2.16	1.79	1.97	2.33	1.56	1.95
80% IWR	Control	1492	1387	2879	1325	1401	2726	1.35	1.24	1.30	1.50	1.05	1.27
	Chitosan	1507	1388	2895	1261	1408	2669	2.22	2.19	2.21	2.48	1.77	2.12
	Liquid paraffin	1518	1401	2919	1279	1414	2693	2.50	2.42	2.46	2.74	1.95	2.35
	Kaolin 5 %	1436	1376	2812	1259	1390	2649	1.78	1.75	1.76	1.93	1.61	1.77
	Titanium dioxide	1473	1379	2852	1268	1399	2667	1.93	2.01	1.97	2.04	1.74	1.89
60% IWR	Control	1108	1022	2130	1001	1072	2073	0.91	0.90	0.90	1.26	0.70	0.98
	Chitosan	1114	1093	2167	1011	1092	2103	1.62	1.46	1.54	1.70	1.05	1.37
	Liquid paraffin	1126	1166	2192	1013	1106	2119	1.93	1.71	1.82	1.93	1.33	1.63
	Kaolin 5 %	1088	1062	2132	1002	1083	2084	1.32	1.13	1.23	1.31	0.76	1.04
	Titanium dioxide	1101	1089	2150	1009	1091	2099	1.44	1.33	1.39	1.61	1.00	1.31

IWR: Irrigation Water Requirement

Results in (Table, 5 and Fig. 3) summarizes the water consumptive use of the various treatments and showed that, irrigation levels positively affected the water consumption in the both years and an increase in irrigation water applied increased seasonal water consumptive use values in two cuts at both seasons. since, the seasonal WCU values at the farmer application treatment was increased by 16.68 and 14.58% more than those under 100% IWR of 2017 and 2018 seasons, respectively. The seasonal WCU values decreased gradually with increasing water stress from 100%IWR up to 60%IWR treatments. Seasonally decreases reached 20.47 and 39.25% with 80 and 60%IWR, respectively in the first season. In the second season, similar trend was observed with decreases reached 21.77 and 38.82%, respectively for same respective treatments compared to 100%IWR. Two seasons' results demonstrated that, water consumptive use was increased as IWR values increased. these results may be attributed to an increase in the soil moisture was more available for extraction by plant roots,

which in turn improves the plant water status and maximize plant growth, which increased transpiration rates as well as the greater flow of water from the soil leading to high evaporation opportunity from the relatively wet soil surface condition (farmer application) rather than dry (60%IWR). These results are in the harmony with those obtained by Okwany *et al.* [33] on spearmint crop. Singh *et al.* [34] reported that increasing soil moisture content was significantly increased crop evapotranspiration of Japanese mint (*Mentha arvensis*) growth in India.

It is evident from Table (5) and Fig. (4) that, antitranspirants did not influence the total seasonal WCU during either season, but-non- perceptible increases were noted in WCU values with control (non-sprayed) as compared with all antitranspirant treatments. The slight increase were 4.31% (season 1) and 1.90% (season 2) obtained with control treatment comparing with Kaolin 5% which, gave the lowest values. Among antitranspirants treatments, maximum seasonal WCU values were recorded

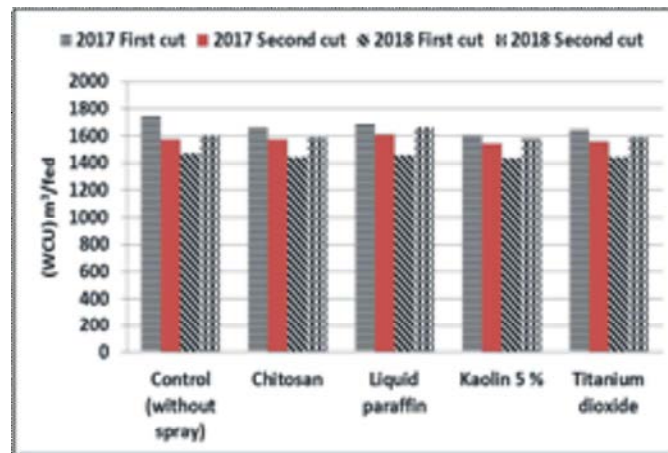


Fig. 4: Water consumptive use m³/fed for spearmint crop affected by antitranspirant of 2017 and 2018

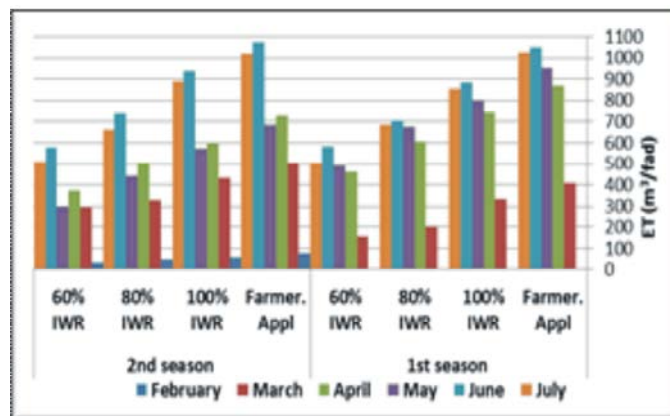


Fig. 5: Monthly water consumptive use for seapmint crop in 2017 and 2018 season.

with liquid paraffin emulsion follows by Chitosan followed by Titanium dioxide and finally Kaolin 5 % and this trend is true for two cuts in both seasons. In this respect Yadov and Singh [35] reported that antitranspirants did not influence the total ET during either growing season of barley crop, but application of a reflecting type of antitranspirant (Kaolin) was most effective in reducing daily ET compared with untreated plants. El Mantawy and El Bialy [36] stated that application of antitranspirants effectively reduced sunflower crop water consumptive use.

The interaction effects of irrigation and antitranspirant treatment, results pointed to a synergy between high level of irrigation and control (without spraying) treatment with respect to water consumed by plants, such that the highest values of seasonal WCU were 4511 and 4057 m³/fed for seasons one and two, respectively obtained from plants irrigated by farmer application and non- spraying , while, the lowest values were 2132 and 2084 m³/fed water consumed at season one

and two, showed with irrigation at 60% IWR with spraying by kaolin antitranspirant. Results also reveal that under water stress at 80% and 60%IWR sprayed plants with antitranspirants, were bit superior in consuming more water than non-sprayed plants, contrariwise to this non-sprayed plants were superior under farmer application and 100%IWR. These results may insure the roles of antitranspirants (waxing type) in the partial closure of the stomata under water stress condition which contributed to improving the water status of plants by saving water in the plant tissues at the early growth stage leading to enhancing the biotic processes, nutrition and increase growth as well as water loss through transpiration at mid-stage and maturity which increase water consumption. The results in are the agreement with those obtained by Kahlel [37].

Monthly Water Consumptive Use: Monthly water consumptive use values for spearmint plants were obtained from the sum of water use for each irrigation

during the month installed in Fig. (5). In general, the highest values of monthly WCU for all months during growing season were recorded with farmer application, while the lowest ones were observed at 60%IWR and, this find was true in both cuts and seasons. Among antitranspirant treatments, results pointed to an increase in WCU with non-sprayed plants under all months. However, WCU values were small in initial stage (March and February) and raised gradually during developed and mid-season stage to reach its maximum increases according to complete crop canopy and higher temperature (early May- April) for cut one, 1st and 2nd season, respectively and (June) for cut two then, slightly declined was noted in WCU values in (late May) cut one and (July) cut two due to maturity stage and harvest time. The results are agreement with those obtained by Zizy *et al.* [38].

Irrigation Water Productivity of Fresh Weight Kg/m³ water Applied (IWP): The results in Table 5 showed that irrigation with 100% or 80%IWR obtains maximum values of IWP almost identical, with differences less than 5%, but 100%IWR gave values of IWP were slightly more than 80%IWR in the two seasons, except the second cut of the first season, where irrigation, as 80% IWR was eminent.

The overall maximum average value was 1.94 kg/m³ water for each season, respectively. Whereas, the minimum average values of IWP (1.33 and 1.34 kg/m³) were resulted with farmer application treatment for first and second seasons respectively. Results reveal also, that IWP was higher in 1st cut than the 2nd cut at both growing seasons. The results may reflect the importance of weather conditions, which IWP was decreased under hot summer conditions due to more irrigation water applied to plants and less fresh weight due to heat stress. These results are in agreement with those obtained by Moussa [39] and Zizy *et al.* [38].

Spraying plants with liquid paraffin antitranspirants obtained maximum values of IWP in the two cuts in both seasons were 2.08 and 2.01 kg/m³ for seasons 1 and 2, respectively. The average values of IWP decreased for non-sprayed plants (control) by 43.8% and 40.0% in the 1st and 2nd seasons, respectively comparing to maximum values. The interaction between 80%IWR and liquid paraffin recorded almost maximum values of IWP being 2.46 and 2.35 at season one and two, respectively, whereas minimum IWP value was 1.04 in both season recorded under farmer application with non-sprayed plants (control). Table 5. This results may be reflecting the important of determining IWP and irrigation at 80%IWR,

instead of 100%IWR, which more than 30% of IWA can be saved compare to farmer application, in order to achieve and ensure the base of more crop per less drop in the crop production.

Water Use Efficiency kg Dry Weight /m³ Water (WUE): Values of water use efficiency as recorded in Table (6) indicate that, irrigation at 80% IWR gave the maximum water use efficiency of dry weight were 0.693 and 0.680 kg dry weight/ m³ water for cut one and two in 2017 season respectively, while the minimum values of 0.398 and 0.373 kg dry weight/ m³ were recorded at farmer application treatment. In 2018 season the same trend was noticed whereas, the maximum values were 0.651 and 0.484 kg / m³ water, while the minimum values being 0.365 and 0.300 kg/ m³ for the same respective cuts.

The two-season results clearly demonstrated that water use efficiency was reduced with increasing water rate in both cuts. These results are in harmony with those reported by [13] and Okwany *et al.* [40] who stated that water-use efficiency of spearmint crop improved significantly for both harvests with increasing water deficit.

The effect of foliar spraying of antitranspirants, as installed in Table 6 reveal that, WUE was positively increased in response to spraying all foliar application treatments as follows: Liquid paraffin > Chitosan> Titanium dioxide > kaolin as compared with control (unsprayed plants) and this trend was true for both cuts under two seasons. The highest values of WUE were 0.743 and 0.664 for cut one and two under season 1, the corresponding values at season 2 were 0.710 and 0.506 for cut one and two, respectively obtained with liquid paraffin. However the lowest values were 0.393 and 0.372 for cut one and two under season 1. Corresponding values at season 2 were 0.418 and 0.282 for cut one and two, respectively resulted from non-spraying plants (control).

The interaction between irrigation regimes and foliar spraying of antitranspirants, was benefit to alter such WUE in both cuts under two seasons and the highest WUE value was obtained for irrigated according to 80% IWR at both season combined with spraying liquid paraffin antitranspirants. Whereas values were 0.880 and 0.860 for cut one and two under season 1 and 0.836 and 0.578 for cut one and two at season 2, respectively. The results clarify the role of these antitranspirants substances in related to reducing water loss from plants through transpiration, as a result of the partial closing of the stomata as reported by Abdallah *et al.* [41] which

Table 6: Dry weight water use efficiency (kg/m³) and oil yield water use efficiency (ml/m³) of spearmint plants as affected by irrigation regime and antitranspirants and their interactions in 2017 and 18 seasons

Tested variable	Water use efficiency of Dry Weight kg/m ³ water						Water use efficiency of oil yield g/m ³ water					
	1 st season			2 nd season			1 st season			2 nd season		
	First cut	Second cut	Seasonal	First cut	Second cut	Seasonal	First cut	Second cut	Seasonal	First cut	Second cut	Seasonal
Irrigation Treatments												
Farmer application	0.398	0.373	0.385	0.365	0.300	0.333	3.46	4.37	3.91	3.53	3.94	3.73
100% IWR	0.664	0.600	0.632	0.663	0.470	0.577	6.18	7.90	7.04	6.79	6.88	6.83
80% IWR	0.693	0.680	0.687	0.651	0.484	0.567	8.12	9.73	8.93	8.45	7.68	8.06
60% IWR	0.575	0.492	0.533	0.555	0.345	0.503	6.14	6.70	6.42	6.59	5.23	5.91
Antitranspirants												
Control (without spray)	0.393	0.372	0.383	0.418	0.282	0.416	4.05	5.09	4.57	4.72	4.27	4.49
Chitosan	0.689	0.638	0.663	0.679	0.484	0.581	6.23	7.55	6.89	6.79	6.34	6.57
Liquid paraffin	0.743	0.664	0.704	0.710	0.506	0.608	9.10	10.52	9.81	9.64	8.86	9.25
Kaolin 5 %	0.520	0.480	0.500	0.466	0.356	0.411	5.87	7.03	6.45	5.83	5.74	5.78
Titanium dioxide	0.569	0.527	0.548	0.519	0.370	0.445	4.63	5.69	5.16	4.71	4.45	4.58
Interaction: Irrigation X Antitranspirants												
Irrigation	Antitranspirants											
Farmer Application	Control	0.253	0.242	0.247	0.280	0.190	0.235	2.25	2.49	2.37	2.66	2.42
	Chitosan	0.437	0.442	0.439	0.452	0.403	0.428	3.62	4.95	4.29	4.16	4.60
	Liquid paraffin	0.524	0.480	0.502	0.472	0.415	0.443	5.45	6.81	6.13	5.42	5.97
	Kaolin 5 %	0.345	0.319	0.332	0.326	0.259	0.293	3.04	3.67	3.35	3.16	3.29
	Titanium dioxide	0.432	0.380	0.406	0.296	0.233	0.265	2.94	3.92	3.43	2.22	2.65
100% IWR	Control	0.447	0.414	0.430	0.502	0.372	0.441	4.02	5.75	4.89	5.02	5.37
	Chitosan	0.830	0.722	0.776	0.771	0.548	0.666	7.22	8.09	7.66	7.40	7.12
	Liquid paraffin	0.838	0.734	0.786	0.800	0.533	0.703	8.80	11.68	10.24	9.28	9.33
	Kaolin 5 %	0.532	0.525	0.528	0.533	0.437	0.490	5.37	7.77	6.57	5.96	7.17
	Titanium dioxide	0.675	0.603	0.639	0.707	0.458	0.587	5.47	6.21	5.84	6.29	5.78
80% IWR	Control	0.494	0.455	0.474	0.456	0.327	0.391	5.72	6.73	6.23	5.88	5.36
	Chitosan	0.806	0.807	0.806	0.784	0.543	0.664	7.82	10.24	9.03	8.39	7.66
	Liquid paraffin	0.880	0.860	0.870	0.836	0.578	0.707	12.85	14.27	13.56	13.54	10.64
	Kaolin 5 %	0.650	0.622	0.636	0.600	0.489	0.544	8.64	9.71	9.18	8.81	8.46
	Titanium dioxide	0.635	0.658	0.647	0.578	0.483	0.531	5.59	7.70	6.64	5.61	6.28
60% IWR	Control	0.379	0.378	0.379	0.432	0.241	0.603	4.20	5.37	4.79	5.31	3.80
	Chitosan	0.681	0.582	0.632	0.708	0.441	0.574	6.27	6.93	6.60	7.22	5.82
	Liquid paraffin	0.731	0.582	0.656	0.734	0.500	0.617	9.28	9.31	9.30	10.34	8.90
	Kaolin 5 %	0.552	0.452	0.502	0.406	0.237	0.322	6.44	6.96	6.70	5.36	4.05
	Titanium dioxide	0.532	0.465	0.498	0.495	0.307	0.401	4.53	4.93	4.73	4.70	3.59

IWR: Irrigation Water Requirement

increase biotic processes; i.e. Photosynthesis and helps the healthy growth of the plant resulting an increases in the plant final yield ; and this is reflected in increasing water use efficiency for this treatments compared with the other treatments especially under acceptable water shortage. These results are in agreement with Ahmed [42] and Kahlel [37]. Recently, El Mantawy and El Bialy [36] who stated that application of antitranspirants, effectively reduced water consumptive use and enhanced water productivity of sunflower crop specially under irrigation water shortage conditions.

Water Use Efficiency (WUE) of Oil Yield ml/m³ Water Consumed: Results presented in (Table 6) showed that irrigation at 80%IWR was superior in maximizing WUE followed by 100%IWR compared to other irrigation treatments for both cuts and two successive seasons of study. Seasonal average values were 8.93 and 8.06 ml/m³ water in season 1 and 2 respectively. The maximum WUE of 8.12 and 9.73 ml/m³ water for 1st and 2nd cuts in season 1 were obtained with 80%IWR, season 2 values

were 8.45 and 7.68 for 1st and 2nd cut respectively. The minimum values of 3.64 and 4.37 ml/m³ for 1st and 2nd cut in season 1 were recorded with farmer application treatment. In second season, the same trend was found with corresponding values being 3.53 and 3.94 ml/m³ water.

Results showed also, slight increase in WUE at 2nd cut. The two-season results, indicate that WUE for oil yield increased with decreasing amount of water applied according to irrigating at moderate percentage of IWR. This may be due to more oil concentration in leaf of plants companied of adequate oil yield production under 80% IWR, or acceptable oil concentration coupled with high oil production under 100% IWR lead to improve efficiency of water use for oil yield. Mukesh [43] reported that an increase in oil yield could be mainly due to high herbage yield due to increase in leaf number increased the photosynthetic area. It facilitated the crop for more vegetative growth and accumulation of secondary metabolites to form more oil under suitable soil moisture. Results are in harmony with those reported by Marino *et al.* [44].

As for the spraying of antitranspirants, results recorded in (Table 6) showed that all application of antitranspirants was positively increased efficiency of water use (WUE) of oil yield compared with the non-sprayed plants in both cuts at two seasons. The highest values of WUE oil yield were 9.81 and 9.25 ml/m³ water as an average of two cuts under season 1 and 2 respectively obtained with liquid paraffin. On the contrary, non -sprayed plants (control) treatment showed lowest values of WUE were 4.54 and 4.49 ml/m³water as an average of two cuts under season 1 and 2, respectively. Moreover, Titanium dioxide reduced the water use efficiency of oil compared to other antitranspirants.

Concerning the interaction effects, irrigating plants sprayed with liquid paraffin improved the efficiency of water use for oil production compared with all other treatments under every individual level of irrigation in both seasons. Furthermore, it is noted that WUE of oil yield was lowered by more than 70% in plants non -sprayed and received an excessive amount of water (farmer application IWR) compared to the highest values results from spraying with liquid paraffin combined with irrigation at 80% IRW two season results indicate that sprayed plants with liquid paraffin enhanced WUE of oil yield as under study condition. These results are in harmony with those obtained by El-Said [45].

Crop Coefficient (Kc): Crop coefficient (Kc) under 100% IWR as adopted irrigation was calculate and compered with Kc FAO included in "CROPWAT8" output to asses crop coefficient (Kc) of spearmint crop under Middle Egypt condition.

Results shown in Table 7 and in installed in Fig. (6 a & b) and (7 a & b) indicate that monthly kc values started small according to the less plants cover in the early stage, then increased to reach their maximum values in mid-season (late April - mid-May) for cut one and (late Jun - mid-July) for cut two as a result of a complete crop canopy with the highest value of actual evapotranspiration (Eta), due to an increase in weather factors (i.e. temperature, solar radiation and wind speed) and then tended to decline against until the crop harvest (late May) cut one and (late July) cut two. Overall average values of Kc were 0.62, 0.65, 0.95, 0.79, 0.88 and 0.89 for months from February tile July. In additional, Kc FAO values were higher under all month and grow stage than obtained from this study, clarifying the importance of deterring and using local ones. In this respect, Doorenbos and Pruitt [46] and Abbas *et al.* [47] come to same conclusions.

Growth, Yield and Some Yield Attributes

Plant Length: Data tabulated in Table (8) reveal that, significant effect was found on plant length due to increasing irrigation regime from 60% IWR up to farmer application in both cuts of both seasons. The tallest plants were 42.80 and 42.27 cm/plant in 1st and 2nd cut for the 1st season in case of 100%IWR; the similar values were 72.27 and 51.67cm/plant respectively in 2nd season, while the shortest plants were resulted from irrigating plants at 60% IWR treatment. It could be due to, increasing water applied to plant led to keep higher moisture content in the shallow root zone of mint plants and this in turn might favor the plant cell developments that lead to increase the plant shoots growth. These results are in agreement with those of Elansary *et al.* [48] who stated that, when water stress increased, the values of plant length decreased significantly.

With regard to the effect of foliar spraying of antitranspirants, plant length was significantly increased in response to spraying all foliar application as follows: liquid paraffin > chitosan> titanium dioxide > aluminum silicate (kaolin) as compared with the untreated (control) plants.

The highest values of plant length were recorded with spraying plants by liquid paraffin arranged around 44.5cm for the two cuts of the season 1 and the corresponding values being 67 and 51.67cm in season 2. However, differences between the tallest and the shortest plant were 23.28 and 27.40 % in the first season and 25.25and 36.77% in season2 for first and second cuts respectively.

The interaction between irrigation regimes and foliar spraying of antitranspirants, was significantly to altered such trait in both cuts of the two seasons and the tallest plants were obtained for irrigated according to (100% IWR) combined with spraying liquid paraffin antitranspirants.

Leaf Area Index (LAI): Leaf area index was significantly reduced with decreasing water apply from farmer application to 60% in the two cuts under both studied seasons, as shown in Table (8). The highest values of 3.47 and 2.48 for 1st and 2nd cuts (season1) and 3.18 and 2.48 for 1st and 2nd cuts in season 2, respectively resulted under irrigation at farmer application. However the lowest values were shown with irrigating plants at 60% IWR. Comparable values for 60% IWR were 1.54 and 1.02 for 1st and 2nd cuts (season1) and 1.69 and 1.02 for 1st and 2nd cuts in (season 2) respectively.

Table 7: References and actual evapotranspiration (Eto and Eta) and Crop coefficient (Kc) of spearmint crop at El-fayoum region in 2017 and 2018 seasons.

Season	2017			2018			Average Kc
Month	Eto	Eta	Kc	Eto	Eta	Kc	
February	-	-	-	93	58	0.62	0.62
March	559	338	0.61	567	431	0.76	0.65
April	789	760	0.96	612	571	0.93	0.95
May	911	786	0.86	895	596	0.67	0.79
June	993	878	0.88	1068	937	0.88	0.88
July	982	856	0.87	983	891	0.90	0.88
Seasonal	4233	3618	0.85	4124	3426	0.83	0.8

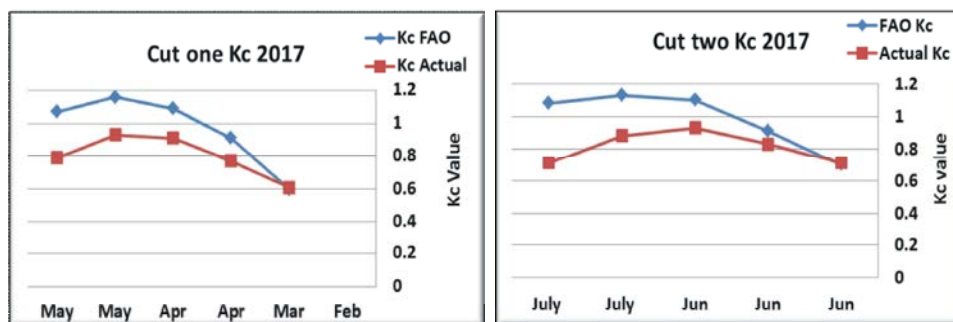


Fig. 6: a and b; Crop coefficient (Kc) of spearmint crop grown at El-fayoum region in under 100% IWR compared with Fao Kc for both cuts of 2017 growing season

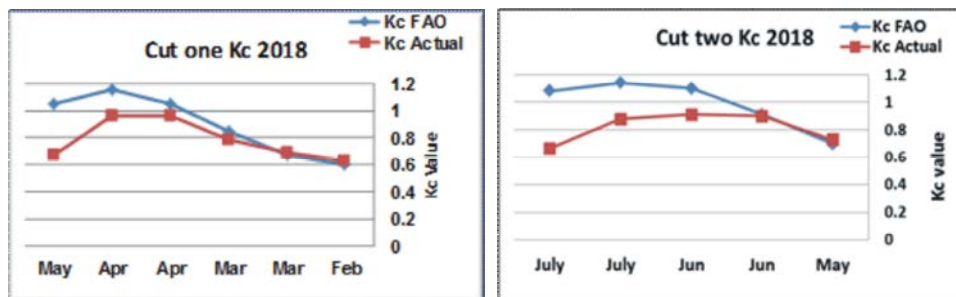


Fig. 7: a and b; Actual crop coefficient (Kc) of spearmint crop grown at El-fayoum region under 100% IWR compared with Kc FAO for both cuts of 2018 growing season

Irrigation can affect the development of the leaf area and the production of dry weight. So, the leaf area index is an important characteristic for the yield and the commercial products of the aromatic and medicinal plants.

Under water-stressed conditions, water uptake into the cytoplasm and vacuole of cell decreases, which reduces cell expansion and subsequently, inhibit the leaf elongation, which decreases in leaf area and subsequently leaf area index and photosynthetic rate per unit of leaf area due to stomatal closure [49]. Stomatal closure inhibits the supply of carbon dioxide to parenchyma cells, which further affects the photosynthetic efficiency by inhibiting CO₂ assimilation and light reaction [50].

The application of antitranspirants induced significant increase in leaf area index of spearmint as

compared with control (without foliar spray) except for aluminum silicate. The highest leaf area index was observed with the plants sprayed by liquid paraffin emulsion when compared with control treatment. The increase rates were 92.98% and 79.38% for 1st and 2nd cuts of season1 and were 82.53% and 79.71% for 1st and 2nd cuts (season 2) respectively. The best positive effective result in the leaf area index was appeared when plants irrigated at farmer application and spraying liquid paraffin, which forms a thin film on leaves under the effect of sunlight reaching high resistance and elasticity. Such film reduces the escape of water from the plant and decreasing transpiration losses, improving plant water status, decreasing wilting and leaf abscission. It is considered a safe substance for the environment [51].

Table 8: Effect of irrigation rate and some antitranspirant treatments on the plant length (cm) and Leaf area index of spearmint plants during the two seasons of 2017 and 2018

		Plant length (cm.)				Leaf area index			
		1 st season		2 nd season		1 st season		2 nd season	
		1 st cut	2 nd cut	1 st cut	2 nd cut	1 st cut	2 nd cut	1 st cut	2 nd cut
Irrigation Treatments									
Farmer application		41.67	41.47	66.47	40.67	3.47	2.48	3.18	2.48
100% IWR		42.80	42.27	72.27	51.67	2.88	2.24	2.77	2.24
80% IWR		39.60	40.40	56.27	44.47	2.27	1.80	2.42	1.80
60% IWR		34.07	30.27	39.80	37.80	1.54	1.02	1.69	1.02
LSD 5%		3.613	2.384	1.683	4.373	0.23	0.28	0.27	0.48
Antitranspirants treatments									
Control (without spray)		34.33	32.25	50.08	32.67	1.81	1.38	1.92	1.38
Chitosan		41.50	41.08	63.33	48.67	2.64	2.06	2.69	2.06
Liquid paraffin		44.75	44.42	67.00	51.67	3.49	2.48	3.50	2.48
Aluminum silicate (Kaolin)		37.42	36.25	54.75	40.33	2.23	1.58	1.82	1.58
Titanium dioxide		39.67	39.00	58.33	44.92	2.54	1.94	2.65	1.94
LSD 5%		4.724	2.163	1.951	2.553	0.27	0.47	0.33	0.57
Interaction									
Irrigation Treatments	Antitranspirants								
Farmer application	Control (without spray)	36.33	33.33	58.00	35.67	2.53	1.91	2.50	1.91
	Chitosan	41.67	43.00	70.33	42.33	3.92	2.51	3.63	2.51
	Liquid paraffin	46.18	46.33	74.00	47.67	4.81	3.17	4.31	3.17
	Aluminum silicate	39.67	39.00	65.00	37.33	3.63	2.29	2.35	2.29
	Titanium dioxide	44.67	40.33	65.00	40.33	2.47	2.55	3.14	2.55
100% *IWR	Control (without spray)	35.00	37.33	64.00	36.00	2.00	1.74	2.47	1.74
	Chitosan	46.00	44.00	79.67	60.00	2.82	2.46	3.07	2.46
	Liquid paraffin	53.00	51.67	81.33	61.67	3.68	2.88	3.92	2.88
	Aluminum silicate	39.33	41.00	64.67	49.67	2.44	1.74	2.03	1.74
	Titanium dioxide	40.67	42.67	71.67	51.00	3.46	2.39	2.34	2.39
80% IWR	Control (without spray)	38.33	33.67	47.67	33.33	1.73	1.19	1.68	1.19
	Chitosan	41.00	44.00	59.33	50.00	2.26	2.08	2.53	2.08
	Liquid paraffin	42.00	45.00	65.67	53.00	3.18	2.50	3.24	2.50
	Aluminum silicate	37.67	37.00	54.00	39.33	1.84	1.46	1.84	1.46
	Titanium dioxide	39.00	42.33	54.67	46.67	2.34	1.78	2.84	1.78
60% IWR	Control (without spray)	27.67	24.67	30.67	25.67	0.97	0.69	1.02	0.69
	Chitosan	37.33	33.33	44.00	42.33	1.54	1.19	1.54	1.19
	Liquid paraffin	38.00	34.67	47.00	44.33	2.28	1.38	2.54	1.38
	Aluminum silicate	33.00	28.00	35.33	35.00	1.02	0.81	1.07	0.81
	Titanium dioxide	34.33	30.67	42.00	41.67	1.88	1.03	2.26	1.03
LSD 5%		9.448	4.325	3.902	5.107	0.55	0.93	0.67	1.14

* IWR = Irrigation Water Requirement.

Fresh and Dry Weights g/plant: The average values of fresh and dry weight (g plant^{-1}) as recorded in Table (9) indicate that, decreasing irrigation water apply rates from 100% to 60% IWR caused significant decrease in fresh and dry weight/plant in both cuts of the two seasons. The reductions in fresh weight/plant were 57.72 and 57.11% for first and second cuts of 1st season and the corresponding values for 2nd season being 57.64 and 65.09% respectively. However, the reduction values for dry weight/plant were 48.41 and 48.55% for cuts 1 and 2 of 1st season and 47.16 and 56.21% for 2nd season respectively. The decreases of water at 60% IWR, may be

due to the deficiency of nutrient absorption which affected vital processes such as photosynthesis, stomata close which, leads to reduced cell division and elongation, activity of plant enzymes and hormones [52], a deterioration in plant growth characters (*i.e.*, plant length and leaf area) and crop development leading to a reduction in the final product represented by the fresh and dry weight. This confirms the sensitivity of spearmint to water stress. Similar results, the fresh and dry weights of mint were decreased with the irrigation water stress because of vegetative growth (*i.e.*, plant length and leaf area), which decreased under water deficit conditions [33].

Table 9: Effect of irrigation rate and some antitranspirant treatments on herb fresh weight and dry weight (g/plant) of spearmint plants during the two seasons of 2017 and 2018

		Fresh weight(g)				Dry weight(g)			
		1 st season		2 nd season		1 st season		2 nd season	
		1 st cut	2 nd cut	1 st cut	2 nd cut	1 st cut	2 nd cut	1 st cut	2 nd cut
Irrigation Treatments									
Farmer application		109.77	95.69	100.57	89.37	23.38	20.48	18.54	16.61
100% IWR		136.07	113.10	126.37	102.87	32.70	27.64	28.01	22.77
80% IWR		103.90	95.22	97.68	80.17	27.28	24.97	21.95	17.97
60% IWR		57.53	48.51	53.53	35.91	16.87	14.22	14.80	9.97
LSD 5%		3.16	2.01	2.76	2.25	0.85	0.59	0.62	0.45
Antitranspirants treatments									
Control (without spray)		74.25	63.45	73.73	55.12	17.49	14.99	15.87	11.81
Chitosan		116.16	100.08	105.88	86.57	29.59	25.98	25.11	20.25
Liquid paraffin		128.59	109.76	116.67	97.59	32.41	27.68	26.50	21.93
Aluminum silicate (Kaolin)		86.12	78.96	79.72	68.71	21.33	19.05	17.33	14.87
Titanium dioxide		103.96	88.40	96.69	77.40	24.45	21.43	19.32	15.29
LSD 5%		2.1	2.74	2.48	2.71	0.58	0.65	0.52	0.70
Interaction									
Irrigation Treatments	Antitranspirants								
Farmer application	Control	86.56	74.27	85.23	62.60	15.90	13.64	14.44	10.61
	Chitosan	125.21	109.94	107.88	104.85	25.48	24.40	22.83	22.19
	Liquid paraffin	136.66	116.47	123.33	119.14	31.32	26.69	24.02	23.21
	Aluminum silicate	87.53	84.06	81.20	70.47	19.42	17.11	15.02	12.82
	Titanium dioxide	112.89	93.69	105.23	89.81	24.78	20.56	16.37	14.21
100% *IWR	Control	102.57	84.76	98.07	80.22	23.49	19.41	21.63	17.69
	Chitosan	157.10	127.68	144.28	114.80	40.66	33.05	32.48	25.85
	Liquid paraffin	167.70	139.16	152.20	126.33	41.23	34.21	34.04	28.25
	Aluminum silicate	109.87	103.00	104.37	96.40	25.33	23.75	22.19	20.49
	Titanium dioxide	143.12	110.89	132.93	96.61	32.80	27.76	29.69	21.58
80% IWR	Control	71.70	61.43	68.46	51.90	19.48	16.69	15.98	12.11
	Chitosan	117.86	108.61	113.24	87.58	32.14	29.62	26.16	20.23
	Liquid paraffin	132.98	119.91	125.02	95.67	35.34	31.86	28.27	21.63
	Aluminum silicate	94.46	86.72	88.43	79.66	24.68	22.66	19.97	17.99
	Titanium dioxide	102.50	99.42	93.27	86.05	24.75	24.00	19.40	17.89
60% IWR	Control	36.17	33.32	43.17	25.78	11.10	10.23	11.44	6.83
	Chitosan	64.47	54.08	58.11	39.06	20.08	16.84	18.94	12.73
	Liquid paraffin	77.02	63.50	66.13	49.24	21.77	17.95	19.66	14.63
	Aluminum silicate	52.63	42.07	44.88	28.31	15.89	12.70	10.77	6.79
	Titanium dioxide	57.33	49.58	55.33	37.15	15.49	13.40	13.20	8.86
LSD 5%		4.18	5.49	4.96	5.43	1.17	1.03	1.04	1.40

* IWR = Irrigation Water Requirement

On the other hand, increasing irrigation rates from 100% IWR to farmer application caused significant decrease in fresh and dry weight/plant in both cuts of the two seasons. The reductions were 19.33 and 15.39% for 1st season and were 20.42 and 13.12% for 2nd season, respectively. Corresponding values for dry weight/plant were 28.50 and 25.90% for cuts 1 and 2 of 1st season and 33.18 and 27.05% for 2nd season, respectively. The excess water can increase the potential for root diseases and microbial growth which can cause the formation of sulfides and butyric acid that are toxic to plants. This all lead to negative impacts yield and wastes water and energy resources [53].

Regarding foliar spraying of antitranspirants, results show a positive significant effect on fresh and dry weight/plant. The highest values of 128.59, 109.76 g plant⁻¹ fresh weight and 32.41, 27.68 g plant⁻¹ dry weight for 1st and 2nd cuts (Season1). However, it were 116.67 and 97.59 g plant⁻¹ fresh weight and 26.50 and 21.93 g plant⁻¹ dry weight for 1st and 2nd cuts (season 2) were obtained with spraying plants by liquid paraffin emulsion, while the lowest values appear accompanied with untreated plants, which recorded 74.25, 63.46, 73.73 and 55.12g plant⁻¹ fresh weight and 17.49, 14.49, 15.87 and 11.81g plant⁻¹ dry weight in both cuts during both seasons, respectively.

The effect of the interaction between irrigation regimes and foliar spraying of antitranspirants, was significant in both cuts under two seasons and the highest values were recorded for irrigation according to (100% IWR) combined with spraying liquid paraffin antitranspirants (Table 9). The corresponding values among dry weight being of 41.23 and 34.21 g/plant for 1st and 2nd cuts (season1) and 34.04 and 28.25g/plant for 1st and 2nd cuts (season 2) resulted from spraying plants with liquid paraffin, while the interaction between irrigation plants at (60% IWR) with spraying foliar titanium dioxide showed the lowest values of dry weight followed by 60% IWR without antitranspirants. This trend was true in both cuts under two seasons. The positive impact of foliar spray with antitranspirants (liquid paraffin emulsion) increases water content in plant tissues which bit decrease the transpiration rate, improving plant metabolism and lead to maximize yield component [54]. Also, foliar-applied mineral oil such as paraffin oil improved the contents of endogenous hormones (IAA, GA₃) and reduced inhibitors (ABA) which led to enhancing growth parameters and photosynthetic pigments hence increased the yield of plant [55].

Effect of Different Irrigation Levels and Foliar Antitranspirants on Essential Oil and its Component

Volatile Oil Percentage and Yield ml/plant: Data installed in Table (10) show that, irrigation had a significant effect on volatile oil of spearmint plants. The highest value of volatile oil percentage were recorded in irrigated with 80% IWR being ; 1.16, 1.43 and 1.28, 1.58 % as compared to other irrigation treatments for the two cuts in both seasons, respectively. However the lowest values of volatile oil percentage were results from plants irrigated with farmer application which recorded 0.86, 1.15 and 0.95, 1.27% in both cuts during both seasons, respectively. This is in harmony with Bettaieb *et al.* [56] who reported that, the essential oil content of *Salvia officinalis* plants increased from 0.39% under 100% of field capacity (water control treatment) to 1.01% under 50% of field capacity, respectively. The increase of essential oil content under drought conditions may be related to a higher density of oil glands, mainly due to the reduction in leaf area as a consequence of the stress generated by the water deficit.

Data also indicated that, volatile oil percentage was significantly increased with foliar spraying of

antitranspirants as compared to control (without spraying of antitranspirants). This trend was true in both cuts in the two seasons and the maximum oil % was obtained with spraying liquid paraffin comparing with control treatment.

The increase rate was 48.15 and 46.73 % for 1st and 2nd cuts (season1), similar values for (season2) were 50.56 and 46.22 respectively. The most effective interaction was obtained from irrigating at 80% IWR combined with spraying liquid paraffin antitranspirants. As shown in the same Table (10), the volatile oil yield (ml/plant) was influenced significantly by the irrigation regimes in the two cuts during both seasons. The values of 0.32 and 0.38 ml/plant for 1st and 2nd cuts (season1) and 0.29 and 0.34 ml/plant for 1st and 2nd cuts in (season 2) respectively resulted under irrigation at 100%IWR which recorded the highest oil yield (ml/plant). However the lowest values were shown with irrigated plants at 60% IWR. Comparable values for 60% IWR were 0.19 and 0.01 ml/plant for 1st and 2nd cuts (season1) and 0.18 and 0.16 ml/plant for 1st and 2nd cuts in (season2) respectively. Generally, essential oil yield shows decreasing trend as the amount of irrigation water reduced. This result are similar with those reported by Behera *et al.* [57] who stated that, irrigation at 100% pan evaporation (PE) significantly enhanced essential oil yield compared to 60% PE.

Generally, essential oil yield shows decreasing trend as the amount of irrigation water reduced. This result indicated that there is a positive relation with water content of the soil and the essential oil yield. This is in line with Bahreininejad *et al.* [58] on *Thymus daenensis* and Sharmin *et al.* [59] on Japanese mint.

Data also, revealed that, spearmint plants were found to be significantly affected by foliar spraying of antitranspirants, *i.e.* the highest volatile oil yield was observed in the plants sprayed with liquid paraffin emulsion when compared with control treatment. The best effective result in the oil yield/plant was appeared plants irrigated at 80% or 100% IWR with spraying liquid paraffin. It was found that foliar spray liquid paraffin emulsion with 80% IWR gave the highest values of the essential oil yield (0.52 and 0.46 ml/plant) for the 1st cut of the 1st and 2nd season, respectively and 0.53 and 0.40 ml/plant for the 2nd cut of the 1st and 2nd cut of the 2nd cultivation season. While, plants irrigated at farmer application showed the lowest values of essential oil yield in both cuts of both seasons (0.11, 0.14, 0.11 and 0.12ml/plant, respectively).

Table 10: Effect of irrigation rate and some antitranspirant treatments on the volatile oil percentage and oil yield/ dry weight plant (ml)of spearmint plants during the two seasons of 2017 and 2018

		Oil%				Oil yield (ml/plant)			
		1 st season		2 nd season		1 st season		2 nd season	
Irrigation Treatments		1 st cut	2 nd cut	1 st cut	2 nd cut	1 st cut	2 nd cut	1 st cut	2 nd cut
Farmer application		0.86	1.15	0.95	1.27	0.21	0.24	0.18	0.22
100% IWR		0.93	1.32	1.03	1.47	0.32	0.38	0.29	0.34
80% IWR		1.16	1.43	1.28	1.58	0.33	0.37	0.29	0.29
60% IWR		1.07	1.36	1.19	1.51	0.19	0.20	0.18	0.16
LSD 5%		0.04	0.09	0.06	0.11	0.03	0.01	0.03	0.03
Antitranspirants treatments									
Control (without spray)		0.81	1.07	0.89	1.19	0.14	0.16	0.14	0.14
Chitosan		1.10	1.43	1.22	1.59	0.33	0.37	0.31	0.32
Liquid paraffin		1.20	1.57	1.34	1.74	0.39	0.44	0.35	0.38
Aluminum silicate (Kaolin)		0.90	1.18	0.99	1.31	0.19	0.23	0.17	0.19
Titanium dioxide		1.02	1.33	1.12	1.47	0.25	0.29	0.21	0.23
LSD 5%		0.04	0.10	0.05	0.10	0.03	0.03	0.03	0.03
Interaction									
Irrigation Treatments	Antitranspirants								
Farmer application	Control	0.89	1.03	0.95	1.15	0.11	0.14	0.11	0.12
	Chitosan	0.83	1.12	0.92	1.25	0.24	0.28	0.22	0.28
	Liquid paraffin	1.04	1.42	1.15	1.57	0.33	0.38	0.28	0.37
	Aluminum silicate	0.88	1.15	0.97	1.27	0.15	0.19	0.15	0.16
	Titanium dioxide	0.68	1.03	0.75	1.14	0.21	0.21	0.12	0.16
100% *IWR	Control	0.90	1.39	1.00	1.54	0.19	0.20	0.19	0.20
	Chitosan	0.87	1.12	0.96	1.25	0.41	0.49	0.37	0.42
	Liquid paraffin	1.05	1.59	1.16	1.76	0.43	0.54	0.39	0.50
	Aluminum silicate	1.01	1.48	1.12	1.64	0.22	0.27	0.21	0.26
	Titanium dioxide	0.81	1.03	0.89	1.15	0.32	0.38	0.30	0.33
80% IWR	Control	1.16	1.48	1.29	1.64	0.17	0.20	0.16	0.16
	Chitosan	0.97	1.27	1.07	1.41	0.43	0.46	0.38	0.35
	Liquid paraffin	1.46	1.66	1.62	1.84	0.52	0.53	0.46	0.40
	Aluminum silicate	1.33	1.56	1.47	1.73	0.24	0.29	0.21	0.25
	Titanium dioxide	0.88	1.17	0.97	1.30	0.29	0.35	0.25	0.29
60% IWR	Control	1.11	1.42	1.23	1.578	0.10	0.11	0.11	0.08
	Chitosan	0.92	1.19	1.02	1.32	0.24	0.26	0.25	0.22
	Liquid paraffin	1.27	1.60	1.41	1.78	0.28	0.29	0.28	0.26
	Aluminum silicate	1.19	1.54	1.32	1.71	0.15	0.15	0.11	0.09
	Titanium dioxide	0.86	1.06	0.95	1.17	0.17	0.19	0.16	0.14
LSD 5%		0.07	0.20	0.09	0.20	0.05	0.05	0.05	0.05

* IWR = Irrigation Water Requirement

GLC Analysis of Essential Oil: The obtained results are hereafter tabulated in Table (11) showed the different components separated and identified from *Mentha viridis* L. oil samples produced from the plants grown under different irrigation regimes and treated with foliar spray of some antitranspirants by gas chromatography (GC), 9 components were identified. The identified components in spearmint herb oil are α -pinene, sabinene, 1, 8-cineole, limonene, carvone, dihydro carveol acetate, β -caryophyllene, germacrene-D and caryophyllene oxide.

The major fractionated components of essential oil of spearmint plants were carvone ranged around 71.3% and limonene 20.5% followed by 1, 8-cineole that comprise over 90% of the significant components while other components were with lower oil amount. Results of this study showed that, volatile oil of *Mentha viridis* has carvone as the major component is in good agreement with other researches [60]. On other hand, it was observed from the same table that, the essential oil composition was affected by irrigation regime. Also, there was a good

Table 11: Effect of irrigation rate and some antitranspirant treatments on essential oil composition (%) of *Mentha viridis* L. plants during the two seasons of 2017 and 2018

No.	Components	Control				Chitosan				Liquid paraffin				Aluminum silicate				Titanium dioxide			
		60%*	80%	100%	Farmer	60%	80%	100%	Farmer	60%	80%	100%	Farmer	60%	80%	100%	Farmer	60%	80%	100%*	Farmer
		IWR	IWR	IWR	application	IWR	IWR	IWR	application	IWR	IWR	IWR	application	IWR	IWR	IWR	application	IWR	IWR	IWR	application
1	α -Pinene	1.28	1.14	0.9	-	0.37	0.9	0.54	0.95	0.74	0.2	0.46	1.62	1.01	0.38	0.16	1.74	0.88	0.61	-	1.21
2	Sabinene	2.14	2.44	0.3	2.03	1.4	0.76	0.55	1.09	1.25	0.3	0.64	1.46	-	1.39	0.26	2.11	1.75	1.29	0.65	0.73
3	1, 8-cineole	2.89	2.76	2.41	1.85	1.44	2.19	1.61	2.41	2.33	2.41	1.38	2.89	2.72	1.35	2.16	0.92	2.06	2.25	1.83	2.81
4	Limonene	22.4	22.8	17.54	18.92	17.99	19.16	15.24	22.65	20.2	18.94	11.74	20.46	21.35	18.2	17.32	26.11	21.14	19.42	14.45	23.62
5	Carvone	67.32	69.63	76.6	71.65	73.21	74.91	80.23	70.62	73.51	76.5	83.96	71.73	72.18	73.88	77.21	65.45	72.32	74.53	81.15	69.31
6	Dihydrocarveol Acetate	-	-	0.74	3.81	3.82	0.69	0.63	0.46	0.43	0.14	0.55	-	1.16	3.85	0.98	1.2	0.66	0.61	0.6	0.48
7	β -caryophyllene	3.97	1.23	0.91	0.95	0.95	0.95	0.69	0.96	0.81	0.91	0.83	0.97	0.93	0.95	0.82	1.39	0.87	0.82	0.76	1.01
8	Germacrene D	-	-	0.31	0.35	0.36	0.17	0.16	0.38	0.3	0.31	0.13	0.38	0.34	-	0.22	0.6	0.12	0.13	0.13	0.41
9	Caryophyllene oxide	-	-	0.29	0.44	0.46	0.27	0.35	0.48	0.43	0.29	0.31	0.49	0.31	-	0.25	0.48	0.2	0.34	0.43	0.42

* IWR = Irrigation Water Requirement

correlation between carvone and limonene, since there was an increase of carvone content of about 13.78% at 100 % IWR, which recorded minimum values of carvone at 60% IWR. On the contrary, there were differences in limonene content being 7.22% increment with decreasing irrigation water supply from farmer application gradually to 60% IWR. These results agreed with Okwany *et al.* [7] who reported that, a reduction in carvone and an increment in limonene content of spearmint oil after an increase in the deficit irrigation regimes. This suggests an early maturity of the spearmint plants following higher irrigation stress conditions. As well as, the changes in essential oil composition occurring at different irrigation regimes are likely due to the changes of the activity of the related biosynthesis enzymes in response to drought [61].

Water deficit is considered to be a major factor affecting plant growth and synthesis of natural plant products and bioactive constituents. In the case of aromatic crops, water deficit may cause significant changes in the yield and composition of essential oils. Membranes are the main targets of degenerative processes induced by drought. Under water deficit, a decrease in membrane lipid content has been observed in essential oil plants and is correlated with an inhibition of lipid biosynthesis [62]. Data presented in Table (11) indicated also that, the best increase of carvone content at 100% IWR with liquid paraffin emulsion treatments, it achieved 83.96%, followed by 80.23% at 100% IWR with chitosan, but limonene recorded an increase under farmer application with aluminum silicate 26.11% and followed by 23.62% with farmer application + titanium dioxide treatment. Increasing volatile oil ratio with water deficit may be also due to the decrement in total carbohydrates since essential oils are formed as secondary metabolites. Not only oil ratio but also oil composition was affected since some components were increased and other components were decreased.

Proline Content: Data presented in Table (12) show a positive effect due to water stress. Decreasing irrigation water supply from farmer application to 60% IWR increased proline content in spearmint plant in both cuts of the two seasons. The highest content of proline was found in plants under drought stress at 60% IWR followed by 80% then the farmer application, while the lowest concentration of proline was recorded at 100% IWR. The increase in proline content in plants under drought stress may be due to the role of proline as the most important compatible osmolyte in adjusting the cells osmosis of plants under water stress which occurs as a common physiological adaptation to drought conditions. In this consider Karimi, *et al.* [63] reported that, proline is among the common solutes that play major roles in osmotic adjustment. Also, proline may protect membranes from damage and stabilize the structures and activities of proteins and enzymes. On other hand, during the time of stress, proline oxidation leads to oxidative respiration which provides energy to the cell: the oxidation of one molecule of proline capitulates 30 ATP equivalents and is therefore well suitable to keep up high-energy-requiring processes [64].

In general osmotic adjustment and physiological responses to drought stress may allow short-term acclimation to temporary water deficit.

Results reflected significant effect on proline content, since untreated plants (control treatment) obtained highest values in both cuts of two seasons followed by titanium dioxide which was superior in 1st cut of season 1, followed by chitosan, then liquid paraffin treatments. The decrement in the amount of proline in leaf tissues after spraying with antitranspirants may be attributed to decrease of water loss from plant through evaporation and transpiration and this in turn increase the amount of water content in the tissue, resulting to decrease in proline content.

Table 12: Effect of irrigation rate and some antitranspirant treatments on Proline content

		Proline mg/100g				Carbohydrate%			
		1 st season		2 nd season		1 st season		2 nd season	
Irrigation Treatments		1 st cut	2 nd cut	1 st cut	2 nd cut	1 st cut	2 nd cut	1 st cut	2 nd cut
Farmer application		27.12	30.64	29.05	45.41	30.79	31.10	29.48	33.19
100% IWR		19.61	25.78	23.12	33.31	34.05	35.46	30.62	37.64
80% IWR		36.12	38.01	33.34	24.30	31.18	30.85	28.04	32.99
60% IWR		51.60	44.52	38.10	29.38	29.59	29.50	26.06	29.83
LSD 5%		1.49	1.49	1.54	0.90	0.33	0.26	0.42	0.30
Antitranspirants treatments									
Control (without spray)		38.65	40.57	38.98	36.02	25.95	26.13	23.95	27.20
Chitosan		32.65	32.08	28.79	32.61	34.15	34.71	31.12	36.59
Liquid paraffin		27.25	28.45	21.27	29.08	36.31	37.56	32.35	39.40
Aluminum silicate (Kaolin)		35.17	38.24	33.75	35.31	29.17	28.73	26.33	30.03
Titanium dioxide		34.33	34.34	31.73	32.47	31.44	31.51	29.01	33.84
LSD 5%		0.99	1.62	1.00	1.15	0.25	0.27	0.38	0.25
Interaction									
Irrigation Treatments	Antitranspirants								
Farmer application	Control (without spray)	31.52	33.93	34.26	28.72	25.13	21.98	25.51	25.02
	Chitosan	26.58	30.98	28.08	30.57	35.10	36.23	31.95	36.23
	Liquid paraffin	18.72	26.90	20.37	27.56	36.52	39.74	32.87	41.89
	Aluminum silicate	28.54	32.82	30.29	31.52	26.70	26.47	27.16	28.56
	Titanium dioxide	30.24	28.56	32.27	28.54	30.48	31.08	29.88	34.20
100% *IWR	Control (without spray)	20.89	21.16	22.94	20.17	25.13	29.71	26.27	30.74
	Chitosan	21.17	29.53	26.56	28.49	35.10	37.30	32.85	40.80
	Liquid paraffin	16.82	25.73	16.01	24.41	36.52	41.48	34.75	43.57
	Aluminum silicate	15.60	24.90	24.60	22.22	26.70	33.42	28.18	34.21
	Titanium dioxide	23.56	27.55	25.46	26.21	30.48	35.38	31.06	38.87
80% IWR	Control (without spray)	41.41	51.46	46.35	41.72	26.83	27.08	23.29	28.33
	Chitosan	32.77	31.05	29.14	31.03	33.29	33.39	30.76	36.68
	Liquid paraffin	28.88	26.15	22.35	24.92	34.86	35.34	32.52	37.42
	Aluminum silicate	39.81	45.79	37.75	36.10	29.48	28.52	25.52	30.18
	Titanium dioxide	37.70	35.60	31.13	32.77	31.43	29.92	28.10	32.35
60% IWR	Control (without spray)	60.79	55.73	52.36	53.46	22.32	25.74	20.73	24.70
	Chitosan	47.67	36.76	31.36	40.35	32.19	32.61	28.89	31.90
	Liquid paraffin	44.57	35.05	26.35	39.44	33.84	33.67	29.25	34.70
	Aluminum silicate	56.75	49.46	42.35	51.42	28.72	26.52	24.46	27.17
	Titanium dioxide	48.20	45.64	38.06	42.37	30.89	29.66	26.96	29.95
LSD 5%		1.99	3.23	2.00	2.30	0.38	0.42	0.60	0.39

* IWR = Irrigation Water Requirement.

Total Carbohydrates: The percentage of total carbohydrates showed a significant decrease in response to irrigation treatments as shown in Table (12), whereas the maximum values of total carbohydrate content was obtained with 100% IWR as compared with other irrigation treatments in the two cuts under both growing seasons. This decrement due to 60% IWR compared to 100% IWR reached 15.07 and 20.20% for the 1st and 2nd cuts (season1) and 17.50 and 26.18% for the 1st and 2nd cuts (season 2) respectively. These results agreed with those obtained by Abdallah *et al.* [65] who reported that, the

reduction of water holding capacity (WHC) to 60% and 40% in the soil induced significant decreases in carbohydrates percentage and the yield as compared to 80% of WHC.

It could be noticed that from the same table, all antitranspirants significantly affected carbohydrate percentage compared with the control plants (without foliar spray) during the two seasons. The highest values of the carbohydrate percentage obtained by liquid paraffin emulsion were 36.31 and 37.56% for the 1st and 2nd cuts of the 1st season, respectively and were

Table 13: Effect of irrigation rate and some antitranspirant treatments on nitrogen and potassium (%) of spearmint plants during the two seasons of 2017 and 2018

		N				K			
		1 st season		2 nd season		1 st season		2 nd season	
Irrigation Treatments		1 st cut	2 nd cut	1 st cut	2 nd cut	1 st cut	2 nd cut	1 st cut	2 nd cut
Farmer application		1.28	1.11	1.39	1.35	1.22	2.12	1.32	2.12
100% IWR		1.41	1.23	1.45	1.46	1.36	2.28	1.48	2.22
80% IWR		1.09	1.08	1.28	1.25	1.22	2.07	1.17	2.09
60% IWR		0.85	0.87	1.2	1.15	0.98	2.02	1.09	1.94
LSD 5%		0.08	0.04	0.04	0.06	0.04	0.09	0.07	0.09
Antitranspirants treatments									
Control (without spray)		0.92	0.87	1.11	1.08	1.01	1.92	1.00	1.95
Chitosan		1.21	1.20	1.42	1.44	1.30	2.16	1.36	2.17
Liquid paraffin		1.30	1.27	1.6	1.54	1.35	2.36	1.56	2.21
Aluminum silicate (Kaolin)		1.15	0.95	1.18	1.15	1.12	2.05	1.13	2.02
Titanium dioxide		1.22	1.05	1.34	1.29	1.18	2.13	1.27	2.11
LSD 5%		0.045	0.037	0.064	0.052	0.037	0.046	0.037	0.053
Interaction									
Irrigation Treatments	Antitranspirants								
Farmer application	Control (without spray)	1.09	0.80	1.17	1.09	1.13	1.91	1.08	2.01
	Chitosan	1.33	1.15	1.49	1.49	1.27	2.19	1.35	2.19
	Liquid paraffin	1.38	1.17	1.65	1.58	1.28	2.28	1.72	2.22
	Aluminum silicate	1.18	1.09	1.23	1.17	1.15	2.08	1.13	2.07
	Titanium dioxide	1.29	1.12	1.42	1.41	1.25	2.11	1.34	2.12
100% *IWR	Control (without spray)	1.18	1.05	1.19	1.19	1.11	2.08	1.15	1.99
	Chitosan	1.51	1.36	1.53	1.63	1.47	2.21	1.64	2.01
	Liquid paraffin	1.65	1.45	1.76	1.68	1.57	2.73	1.90	2.14
	Aluminum silicate	1.33	1.14	1.29	1.32	1.27	2.18	1.32	2.16
	Titanium dioxide	1.40	1.16	1.46	1.49	1.38	2.20	1.40	2.06
80% IWR	Control (without spray)	0.86	0.79	1.05	1.05	0.98	1.86	0.92	2.27
	Chitosan	1.20	1.31	1.38	1.43	1.39	2.13	1.26	1.73
	Liquid paraffin	1.24	1.41	1.54	1.51	1.43	2.24	1.34	2.03
	Aluminum silicate	1.06	0.82	1.18	1.06	1.11	2.04	1.09	2.11
	Titanium dioxide	1.08	1.08	1.26	1.17	1.16	2.11	1.23	1.84
60% IWR	Control (without spray)	0.45	0.73	1.02	1.00	0.82	1.83	0.86	2.07
	Chitosan	0.74	0.96	1.28	1.19	1.07	2.11	1.18	2.06
	Liquid paraffin	0.83	1.06	1.45	1.39	1.14	2.18	1.27	2.32
	Aluminum silicate	1.03	0.77	1.03	1.04	0.93	1.91	0.10	2.34
	Titanium dioxide	1.11	0.84	1.21	1.11	0.95	2.08	1.11	2.11
LSD 5%		0.091	0.074	0.129	0.105	0.074	0.091	0.074	0.105

* IWR = Irrigation Water Requirement

32.35 and 39.40 for the 1st and 2nd cuts of the 2nd season compared to control which recorded the lowest values of 25.95, 26.13, 23.95 and 27.20% in both cuts of both seasons. Also, under all soil moisture levels, the carbohydrate % increased with all antitranspirant treatments comparing with control and the liquid paraffin showed the highest carbohydrate% with 100% IWR treatment. In this concern Dayer *et al.* [66] reported that, the application of antitranspirant gradually increases the accumulation of carbohydrates, which in turn maintained higher water content in plant tissues and many other important functions that directly affect plant growth.

Chemical Constituents in Plant Leaves (K and N %):

For the individual effect of irrigation levels, data presented in Table (13) indicate that, different (IWR) significantly affected N and K concentrations of spearmint plant. The values of nutrients were significantly decreased with the decrease in irrigation water amount. In this concept, the highest values of the N and K percentages in spearmint leaves were realized when the plants irrigated with 100% IWR followed by farmer application and lastly 60% IWR. Such effect was the same during the two cuts in the two seasons. Generally, irrigation treatment of 60% IWR recorded the lowest

Table 14: Effect of irrigation rate and some antitranspirant treatments on Chlorophyll a, b and B-carotene (mg/g) of spearmint plants during the two seasons of 2017 and 2018

		Chlorophyll a				Chlorophyll b				B-carotene			
		1 st season		2 nd season		1 st season		2 nd season		1 st season		2 nd season	
		1 st cut	2 nd cut	1 st cut	2 nd cut	1 st cut	2 nd cut	1 st cut	2 nd cut	1 st cut	2 nd cut	1 st cut	2 nd cut
Irrigation Treatments													
Farmer application		0.68	0.61	0.48	0.39	0.33	0.25	0.33	0.27	0.33	0.43	0.28	0.33
100% IWR		0.92	0.72	0.60	0.71	0.59	0.43	0.62	0.52	0.51	0.68	0.49	0.57
80% IWR		0.70	0.63	0.55	0.63	0.46	0.37	0.48	0.45	0.39	0.52	0.42	0.51
60% IWR		0.58	0.57	0.49	0.58	0.28	0.30	0.30	0.36	0.27	0.35	0.36	0.42
LSD 5%		0.126	0.089	0.098	0.136	0.106	0.050	0.113	0.056	0.069	0.094	0.080	0.102
Antitranspirants treatments													
Control (without spray)		0.47	0.51	0.48	0.48	0.28	0.29	0.30	0.35	0.28	0.36	0.33	0.23
Chitosan		0.82	0.69	0.60	0.69	0.46	0.43	0.49	0.49	0.41	0.48	0.47	0.43
Liquid paraffin		1.02	0.79	0.56	0.61	0.54	0.37	0.57	0.44	0.46	0.5	0.42	0.37
Aluminum silicate (Kaolin)		0.57	0.56	0.50	0.52	0.38	0.28	0.38	0.33	0.35	0.4	0.33	0.3
Titanium dioxide		0.73	0.61	0.52	0.58	0.41	0.33	0.43	0.39	0.37	0.43	0.39	0.33
LSD 5%		0.184	0.087	0.121	0.164	0.079	0.102	0.083	0.120	0.059	0.079	0.083	0.102
Interaction													
Irrigation Treatments	Antitranspirants												
Farmer application	Control (without spray)	0.53	0.54	0.50	0.29	0.27	0.18	0.29	0.22	0.27	0.36	0.19	0.23
	Chitosan	0.73	0.64	0.52	0.54	0.37	0.36	0.39	0.29	0.36	0.48	0.36	0.43
	Liquid paraffin	0.88	0.71	0.45	0.42	0.37	0.28	0.39	0.34	0.38	0.50	0.31	0.37
	Aluminum silicate	0.52	0.54	0.50	0.31	0.29	0.23	0.21	0.27	0.30	0.40	0.25	0.30
	Titanium dioxide	0.72	0.61	0.45	0.40	0.33	0.20	0.35	0.23	0.32	0.43	0.28	0.33
100% *IWR	Control (without spray)	0.55	0.55	0.54	0.60	0.34	0.36	0.35	0.44	0.30	0.40	0.41	0.49
	Chitosan	1.03	0.79	0.66	0.80	0.71	0.53	0.74	0.64	0.56	0.76	0.58	0.70
	Liquid paraffin	1.44	1.00	0.66	0.79	0.84	0.47	0.88	0.57	0.71	0.94	0.52	0.62
	Aluminum silicate	0.75	0.65	0.53	0.63	0.50	0.35	0.53	0.41	0.45	0.60	0.40	0.48
	Titanium dioxide	0.85	0.61	0.59	0.71	0.57	0.44	0.60	0.53	0.52	0.69	0.52	0.58
80% IWR	Control (without spray)	0.45	0.50	0.45	0.53	0.28	0.33	0.29	0.39	0.29	0.39	0.38	0.45
	Chitosan	0.82	0.70	0.66	0.79	0.49	0.51	0.51	0.62	0.43	0.57	0.55	0.67
	Liquid paraffin	1.00	0.78	0.61	0.62	0.59	0.40	0.62	0.48	0.47	0.63	0.47	0.56
	Aluminum silicate	0.52	0.53	0.51	0.61	0.46	0.25	0.48	0.30	0.40	0.50	0.32	0.39
	Titanium dioxide	0.72	0.64	0.52	0.62	0.47	0.37	0.49	0.45	0.38	0.53	0.39	0.47
60% IWR	Control (without spray)	0.34	0.44	0.42	0.50	0.23	0.28	0.25	0.33	0.25	0.33	0.33	0.39
	Chitosan	0.69	0.62	0.54	0.64	0.28	0.33	0.30	0.40	0.28	0.37	0.38	0.45
	Liquid paraffin	0.76	0.66	0.52	0.62	0.36	0.31	0.38	0.37	0.29	0.38	0.37	0.44
	Aluminum silicate	0.50	0.53	0.45	0.54	0.27	0.29	0.28	0.35	0.24	0.32	0.34	0.40
	Titanium dioxide	0.63	0.59	0.50	0.60	0.27	0.30	0.28	0.36	0.27	0.36	0.36	0.43
LSD 5%		0.368	0.174	0.241	0.328	0.158	0.204	0.166	0.241	0.118	0.159	0.166	0.204

* IWR = Irrigation Water Requirement

values of N and K percentage and this finding could be attributed to the fact that, when soil moisture decreased under water stress condition, the mobility of nutrients in the soil is towered and the rate of nutrients flows to root absorption zone decreased as well as limitation of the plants ability for nutrients uptake of such elements. Similar results were obtained by Ramadan and Omar [54].

Regarding the effect of antitranspirants application, data presented in Table (13) indicate significant increments in NK % comparing with the untreated plants (control) in both cuts of the two seasons. In this regards, foliar spraying of liquid paraffin was the superior as compared with other treatments. On the other hand, untreated plants recorded the lowest values of nutrient % in both cuts of the two seasons. The effect of the interaction between irrigation regime and foliar spraying of antitranspirants on N and K content showed a significant increase Plants sprayed with liquid paraffin

concentration under irrigating at 100%IWR recorded the highest values of N and K content compared with the other interactions in both cuts of the two seasons. The obtained results are consistent with the previous investigations, which pointed out a similar finding Ramadan and Omar [54].

Photosynthetic Pigments (Chlorophyll A, Chlorophyll B and B-Carotene): Data tabulated in Table (14) represent the effect of applied irrigation water on chlorophyll a, b and B-carotene in spearmint leaves. Results showed that, the maximum values of chlorophyll a, b and B-carotene obtained with irrigation at 100%IWR followed by 80% IWR and lastly 60% or farmer application, where the effect was non-significant between 80% 100% IWR in the 2nd cut of both seasons for chlorophyll (b) and in both cuts of 2nd season for chlorophyll (a). The same trend was found with B-carotene content with significance effects of all

irrigation treatments in the two cuts under both seasons. These results were confirmed with Bahreininejad *et al.* [59] on thyme. Under water stress, chlorophyll content decreases due to the damage of chloroplast membrane, reduced activity of enzymes, reduced photochemical efficiency of Photosystem II (PS II) under water stress [67].

Regarding antitranspirant treatments, photosynthetic pigments were significantly increased in response to spraying all foliar antitranspirants as compared with the control (untreated plants). The highest values were results of liquid paraffin or chitosan followed by titanium dioxide then kaolin (Table 14). The same trend was observed with B-carotene in the two cuts of both seasons. With respect to the interaction between treatments there was significant effect and the highest values were obtained for irrigation at 100% IWR combined with spraying plants by liquid paraffin emulsion or chitosan.

CONCLUSIONS

Water-saving and conservation is an essential objective to support the agricultural sector, especially in the newly reclaimed land. Data cleared that scheduling irrigation played an important role in improved crop water productivity, yield components and oil production of spearmint crop as well as antitranspirants which has a positive effect in minimizing water stress impact by improved the plant's hydrophilic status and increase crop production which, return to the economic income of crop. So, the present investigation concluded that irrigated spearmint plants (*Mentha viridis* L.) by drip irrigation method at 100% Irrigation Water Requirement (IWR) (4667m³/fed) with liquid paraffin emulsion as antitranspirants was a benefit to maximize yield and its components, which gave highest the economic returns or at 80 % IWR equal 3738 m³/fed) led to improve the water use efficiency for herb dry weight, oil yield and allowed to save about 32% of IWA compared to farmer application. The amount of water saved can help to irrigate additional newer land as water resource-scarce areas which now are common problems due to climate change and other related natural resource degradation.

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