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Effect of Different Drip Irrigation Rates and Potassium Silicate Spray on Growth and Essential Oil Production of French Basil

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ABSTRACT

A field experiment was done in a private Orchard at Gedilah Village in Al-Mansoura city, Dakahlia Governorate, Egypt, throughout the two summer seasons of 2021 and 2022 under clay soil conditions. The purpose of the research was to study the effect of drip irrigation rates{80, 100 &120% of water requirements (WR)}, potassium silicate as a foliar spray(once and twice at the concentration of 2 g/l)and their combinations on some vegetative growth parameters; plant height (cm), leaves dry weight (g/plant), water use efficiency (WUE), NPK%, total chlorophyll (mg /g F.W.), essential oil percentage and its major components percentages of French basil (*Ocimum basilicum* L.) plant.The obtained results cleared that watering French basil with the rate of 120% WR or/and potassium silicate at 2 g/l as a foliar application twice /cut each season produced the tallest plants, the highest values of N, P, K% and total chlorophyll. In comparison the rate of 100 % of WR + potassium silicate as a foliar application at the rate of 2g/l twice for each cut /season gave the heaviest leaves' dry weight (g/ plant) and the highest values of essential oil percentage compared to the control and other treatments. Moreover, GC-MS analysis discovered that the major constituent of French basil volatile oil was Linalool, which increased under the treatment of 80% WR and sprayed twice of potassium silicate at the rate of 2g/l. The previous findings highlight the synergistic effect of potassium silicate in enhancing chlorophyll assimilation, increasing leaves' dry weight, and essential oil production.

***Keywords**: Basil, irrigation, potassium silicate, essential oil and water use efficiency.*

INTRODUCTION

The annual basil plant (*Ocimum basilicum* L.), a member of the *Lamiaceae* (*Labiatae*) family is used to flavor foods, confectionary items, and beverages. It produces a useful volatile oil and has fragrant leaves that can be used dried or fresh. It is economically significant and is grown all over the world. It has historically been employed in folk medicine to treat a variety of illnesses (Asadollahi *et al*., 2013). Basil oil is rich in vital aromatic constituents, including phenolic compounds, as well as several nutrients such as potassium, magnesium, iron, calcium, A and C vitamins, omega-3, fatty acids and folic acid. Moreover, basil possesses a collection of antioxidants known as polyphenols and specifically flavonoids. These molecules are responsible for the therapeutic properties exhibited by basil, as stated by Khater (2015). In addition, the essential oil of basil is thought to be important for its fungistatic insecticidal, antimicrobial, nematocidal and antioxidant properties and herbicidal as well as for the plant to be elastic to stress types (Adiloğlu, 2021).

Water scarcity is a significant issue that can be attributed to the impacts of climate changes. Hence, it is crucial to mitigate water consumption by implementing water management strategies (Debaeke and Aboudrame, 2004; Jacobsen *et al*., 2012). In semi-arid ecological circumstances, irrigation has a major impact on agricultural productivity and suitable irrigation levels are necessary for the best plant quality and yield. In sustainable agricultural systems, drip irrigation systems which offer a cost-effective way to apply small amounts of water to the soil on a regular basis are essential due to the scarcity of water resources (Wang *et al*., 2022).

According to numerous researchers, using potassium silicate as a spray or component of fertilizer has a significant impact on plant growth (Abd El-Razik *et al*., 2015). Potassium (K) also serves a range of functions inside plants. More than 80 enzymes, including transporter enzymes and enzymes that produce proteins, have been shown to require potassium for either direct or indirect activation in studies (Marschner, 2012). Silicon (Si) is one of the components that helps to support anti-oxidation mechanisms and survive stress (Adrees *et al*., 2015). The most important physiological effects of silicon include improvements in photosynthesis, increased root absorption of nutrients necessary for plant growth and decreased poisoning of sodium ions and heavy metals. In addition, Shehata and Sarhan (2023) indicated that potassium silicate significantly affects the plant height and the herb's dry weight per plant of French basil. The foliar spraying of 2000 ppm K-silicate on basil plants resulted in the best values in herb's fresh and dry weight per plant compared to the control (without spraying).

Therefore, this study aimed to examine the impact of potassium silicate foliar application under some different drip irrigation rates on the growth, essential oil production and water use efficiency of French basil plants grown under field conditions of clay soil in the Nile Delta to state the optimum amount of plant water needs under these conditions.

MATERIALS AND METHODS

A field experiment was performed in a private farm located at Gedilah Village, Al- Mansoura city, Dakahlia Governorate in Egypt during the two summer seasons of 2021 and 2022 under clay soil conditions to study the effect of drip

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irrigation rates [80, 100 and 120% of water requirements (WR)], potassium silicate as foliar application (once or twice spraying each cut at the concentration of 2 g/l) and their combinations on some vegetative growth parameters; plant height (cm) and leaves dry weight (g/plant), water use efficiency (WUE), Chemical composition (N, P, K % and total chlorophyll), volatile oil percentage and its composition of French basil (*Ocimum basilicum* L.) plant.

The chemical and physical analyses of the experimental soil were estimated according to Chapman and Pratt (1978) and listed in Table (1).

Table 1. The chemical and physical properties of the empirical soil (as an average of the two seasons)

Physical analysis													Soil texture
Clay (%)		**Silt (%)**		**Fine sand (%)**				**Coarse sand (%)**					**Clay**
68		14		10				8					
Chemical analysis													
Ph	E.C. (mmhos/cm)	Soluble cations(meq./100g/soil)				Soluble anion(meq./100g/soil)				Available (ppm)			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	CO_3^{-2}	HCO_3^{-}	SO_4^{-2}	N	P	K	
7.14	0.15	0.33	0.37	1.55	0.09	0.71	0.00	0.30	1.33	52	7.5	130	

Climatic data:

Climatic data were taken from an automated weather station located at the empirical site and were presented in Table (2) as monthly averaged from May to August for both seasons 2021 and 2022.

Table 2. Climatic data monthly (as average) during the growing seasons of 2021 and 2022

Months	Air Temperature Max	Air Temperature Min	Relative Humidity (RH)	Wind Speed m/s	Sunshine Duration H	Solar Radiation $MJ/m^2/day$
			First season			
May. 2021	35.3	15.5	46	2.8	11.4	27.9
Jun. 2021	40.1	16	50	2.9	12.5	29.6
Jul. 2021	42.3	20	50	2.9	12.3	29.4
Aug. 2021	43.5	21	52	2.5	11.9	28.4
			Second season			
May. 2022	37.2	13	51	3.1	11.3	27.7
Jun. 2022	39.1	18	50	3.2	12.6	29.5
Jul. 2022	41.5	20	51	2.8	12.4	29.1
Aug. 2022	42.6	21	54	2.7	11.8	28.6

Plant source and cultivation:

The French basil seeds utilized in this study were procured from the Medicinal and Aromatic Plants Research Department, Horticultural Research Institute (HRI), Agricultural Research Center, Giza, Egypt. The basil seeds were sown in the nursery on March 20th for both growing seasons of 2021 and 2022. After 50 days following the initial sowing, when the seedlings reached an approximate height of 15 cm, they were subsequently transplanted to the field on May 10th The transplantation process involved spacing the plants 30 cm apart and maintaining 70 cm between the lines.

Experimental unit and irrigation treatments:

The three experimental main plots were treatments of drip irrigation rates, each main plot with 11.25 m length and 3.75 m width (area = 42.19 m^2) and containing six dipper lines, each two lines representing one replicate. The area of every subplot was 15.75m^2 and contained 72 plants. Additionally, the seedlings were placed on one side of the dipper line, specifically utilizing a drip tube-style GR with a diameter of 16 mm. This drip line was equipped with emitters spaced at intervals of 30 cm and had a discharge rate of 4 l/h. A quantity of 20 cubic meters per feddan of aged organic manure was incorporated into the soil during the pre-cultivation phase in both seasons.

The experiment was irrigated with drip irrigation system, starting on May 10th in both seasons according to the meteorological data of the weather station. The chemical analysis of the used irrigation water is listed in Table (3). A space (3 m in width) was left between each plot to avoid the overlapping infiltration of both irrigation and foliar application treatments and the irrigation treatments were started after 10 days from planting. All treatments in the first 10 days received an equal amount of water. The amounts of applied water irrigation treatment during the growth period are shown in Table (4).

Table 3. The chemical analysis of the used irrigation water (an average of the two seasons)

Characters	E.C.(ppm)	PH	Cations (ppm) Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Anions (ppm) CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}
Value	334.1	8.55	11.0	3.6	312.5	7.0	0.0	28.44	205.4	100.0

The ETo (mm/day) was calculated by the FAO Penman-Monteith method (Allen *et al.,* 1998) The average monthly irrigation requirements (m3/fed.) were represented in Table (4). The irrigation quantities 80% and 120% were derived from 100% irrigation requirement.

The source of potassium silicate and application:

The origin of potassium silicate (K_2SiO_3 as a powder) was the company of Technogene, Dokky, Giza, Egypt. Potassium silicate at 2.00 g/l was applied as foliar spraying after three weeks from the transplanting and after two weeks from the first one. After the first cut, the same rates and application times were applied to each experimental unit.

Experimental design:

The experimental design was a strip plot design with three replicates. Treatments of irrigation were arranged in the vertical plots as follows: (I_1= 80%WR, I_2= 100%WR and I_3= 120%WR), while the foliar application with potassium silicate (KS) was assigned in horizontal plots as follows: (KS_1) = without spray, (KS_2) = spray once and (KS_3) = spray twice. Each vertical plot with 11.25 m length and 3.75 m width (area = 42.19 m^2) and contains six dipper lines, each two lines represents one replicate. The area of every horizontal plot was 15.75 m^2 and contained (18286 plant/feddan), where (fed. = 4000 m^2).

Table 4. The recommended irrigation quantities for French basil during 2021 and 2022 seasons.

Months	Eto	Total monthly irrigation 80 %	Total monthly irrigation 100 %	Total monthly irrigation 120 %
		m^3/fed.	m^3/fed.	m^3/fed.
May. 2021	8.4	216	270	324
Jun. 2021	9.2	414	517	620
Total first cut		630	787	944
Jul. 2021	8.5	198	248	298
Aug. 2021	8.1	382	478	574
Total Second cut		580	726	872
Total 2021		1210	1513	1816
May. 2022	8.1	210	263	316
Jun. 2022	9.0	414	517	620
first cut		624	780	936
Jul. 2022	8.3	192	240	288
Aug. 2022	7.9	373	466	559
Total Second cut		565	706	847
Total 2022		1189	1486	1783

Recorded Data:

Plant growth traits:

Samples of 9 plants were taken randomly for each treatment and labeled to record the different vegetative growth characters as plant height, where the upper parts of plants were cut at 10 cm above the soil surface at the beginning of flowering in both growing seasons (2 cuts for each season, the first cut was on 6th July and the second one was on 27th August), then the height was measured to the highest point of each plant. After the basil fresh leaves were separated and weighed, they were dried at room temperature until constant weight to record the leaves' dry weight (g/plant).

Water use efficiency (WUE):

Water use efficiency (WUE) was estimated according to the equation of Howell *et al.* (1990) as follows:

$$\textbf{WUE} = \frac{Yield\ of\ dry\ leaves\ (kg/fed)}{Water\ quantity\ (m3/fed)} = \textbf{kg/m}^3$$

Chemical composition of leaves:

Mineral content:

Nitrogen, Phosphorus and Potassium (%) were estimated according to Mertens (2005 a and b) where fresh leaves were dried at 70°C for 72 hours and ground to determine the content of (N, P, K) in the dry crushed leaves of basil.

Chlorophyll Pigments Determination:

Represented samples from the third and fourth upper fresh leaves from the apical bud were obtained at the date of harvest to determine total chlorophyll a+ b as (mg/g F.W.) according to Lichtenthaler and Wellburn (1983).

Essential oil percentage:

The essential oil from the dry leaves of French basil samples (100 g) was isolated by hydro distillation for 3 hr. using a Clevenger-type distillation apparatus according to Egyptian Pharmacopeia (1984), then its percentage was recorded.

Essential oil compositions:

Gas chromatography-mass spectrometry (GC-MS) analysis was used to examine the essential oil component from the second season samples. The Trace GC1310-ISQ mass spectrometer (Thermo Scientific, Austin, TX, USA) was used, along with a direct capillary column TG–5MS (30 m x 0.25 mm x 0.25 µm film thickness). The temperature of the column oven was first maintained at 35°C, then increased by 3°C/min to 200°C and kept for 3 minutes. Finally, it was raised by 3°C/min to the ultimate temperature of 280°C and held for 10 minutes. The temperatures of the injector and MS transfer line were maintained at 250 and 260°C, respectively. A steady flow rate of 1 ml/min of helium was employed as the carrier gas. One milliliter diluted sample was automatically injected using an Autosampler AS1300 connected to a GC in split mode, with a three-minute solvent delay. In full scan mode, EI mass spectra were obtained at 70 eV ionization voltages covering the m/z 40–1000 range. For the ion source, a temperature of 200 °C was chosen. Through comparison of retention durations and mass spectra with the mass spectral databases of WILEY 09 and NIST 11, the components were identified.

Statistical analysis*:*

The data were subjected to statistical analysis using the SAS program (SAS, 2000). The statistical significance of the variations in means for all attributes was assessed at a 5% significance level according to Waller and Duncan (1969) and comparing between means was achieved by applying Duncan multiple range method.

RESULTS AND DISCUSSION

Plant Growth Traits:

Data presented in Table (5) reveal that irrigated French basil plants with the rate of 120 % WR (I_3), significantly increased plant height (cm) compared to the other two rates I_1 (80%WR) and I_2 (100%WR) under study during the two cuts for both seasons. The increases in the height of plant (cm) were 10.56 and 12.22 as well as 9.45 and 17.22 for 120% WR rate and 4.56, 6.22 as well as 8.00, 8.67 for 100% WR rate over the lowest rate (80% WR), respectively in both cuts during the two tested seasons. These results indicate the importance of drip irrigation at the appropriate rate in reducing the production of abscisic acid (ABA), which restricts plant growth by negatively affecting root growth, causing defoliation, and lowering mineral absorption (Kumar and Dey, 2011). Moreover, Ekren *et al.* (2012) on purple basil found that the best plant height was recorded from 125% of field capacity treatment for both seasons. Also, Sayarer *et al.* (2023) reported that the plant height of *Ocimum basilicum* L. significantly increased with increasing the irrigation levels (IRL) with 100 and 75% of field capacity (FC) compared to the lowest levels (50 and 25 % FC).

Using potassium silicate as a foliar application significantly increased French basil height compared to the control (without foliar application) for every cut during both seasons (Table 5). It can be noticed that the best treatment in this concern was spraying twice with potassium silicate at the rate 2g/l /every cut /season compared to the other treatments of the study. The increases in plant height were 4.23 cm, 4.22 cm at the first season and 2.89 cm, 4.12 cm in the second season for 2g/l rate as twice application and over control (without foliar spray), respectively. A source of silicon and potassium that is extremely soluble is potassium silicate gives benefits to plants and soil by supplying small amounts of potassium and is mostly utilized as a silica amendment in agricultural production systems (Abou-Baker *et al.*, 2011). Silicon and potassium improve plant development, increase photosynthesis, increase transpiration and evaporation efficiency, strengthen leaves, increase chlorophyll concentration per leaf area, and improve product quality (Talebi *et al.*, 2015). In the same line, El-Leithy *et al.* (2019) revealed that the highest value of plant height of *Nigella sativa* was increased with 8 ml/l potassium silicate spray alone.

Table 5. Effect of different irrigation rates (I) and foliar application of potassium silicate (KS) on plant height (cm) and leaves dry weight (g/plant) of French basil during the two seasons (2021 and 2022)

Treatments		Plant height (cm)				Leaves dry weight (g / plant)			
		First season		Second season		First season		Second season	
		1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Effect of drip irrigation rates									
I_1		55.44c	47.78c	51.44c	40.00c	9.56c	5.33c	7.66c	4.68c
I_2		60.00b	54.00b	59.44b	48.67b	13.03a	9.47a	11.73a	9.10a
I_3		66.00a	60.00a	60.89a	57.22a	12.13b	8.00b	10.33b	7.56b
Effect of potassium silicate									
KS_1		58.44c	51.67c	56.11b	46.44b	10.39c	6.54c	8.89c	5.78c
KS_2		60.33b	54.00b	56.67b	48.89a	11.34b	7.42b	9.80b	6.89b
KS_3		62.67a	55.89a	59.00a	50.56a	12.99a	8.83a	11.03a	8.67a
Effect of the interaction treatments									
	KS_1	51.67e	45.00d	50.00d	40.00f	8.67i	4.33i	6.67i	3.00i
I_1	KS_2	56.00d	48.33cd	50.00d	40.00f	9.33h	5.67h	8.00h	5.03h
	KS_3	58.67d	50.00c	54.33c	40.00f	10.67g	6.00g	8.30g	6.00g
	KS_1	60.00cd	50.00c	58.33b	44.33e	11.50e	8.30d	11.00d	8.00d
I_2	KS_2	60.00cd	54.33b	60.00a	50.00d	12.60c	9.10c	11.40c	8.30c
	KS_3	60.00cd	57.67ab	60.00ab	51.67cd	15.00a	11.00a	12.80a	11.00a
	KS_1	63.67bc	60.00a	60.00ab	55.00bc	11.00f	7.00f	9.00f	6.33f
I3	KS_2	65.00b	60.00a	60.00ab	56.67ab	12.10d	7.50e	10.00e	7.33e
	KS_3	69.33a	60.00a	62.67a	60.00a	13.30b	9.50b	12.00b	9.00b

Means having the same letter in a column are not significant at 5% level, where I_1= 80%WR, I_2= 100%WR, I_3= 120%WR, KS_1 (g/l) = without spray, KS_2 (g/l) = spray once, KS_3 (g/l) = spray twice.

Concerning the combination effect, results presented in Table 5 show that irrigation treatments of 100 and 120 % of WR combined with any potassium silicate treatment significantly increased French basil height compared to the lowest irrigation rate (80% of WR) combined with potassium silicate rates in both cuts during the two consecutive seasons. Increasing irrigation rate from 80 to 100 and 120% of WR gradually increased sweet basil height under each potassium silicate treatment. The highest values of this parameter of French basil plants were achieved with the combination treatment between 120 % of WR and 2g/l/cut/season compared to the other combinations under study. Furthermore, El-Gamal *et al.* (2021) indicated that the application of potassium silicate produced the maximum values of plant growth and yield components of borage plants under irrigation regimes. In addition, Sarhan and Shehata (2023) discovered that a combination of irrigation every 3 and 4 days, along with the application of biochar and a foliar spray of K-silicate, resulted in the largest fruit output and its various components of *Trachyspermum ammi* plant.

Results in the same Table 5 reveal that the highest values in leaves' dry weight (g / plant) were obtained by the treatment of I_2 (100% WR) compared to the other rates under study I_1 (80%) and I_2 (100%) during both seasons for every cut as it recorded; 13.03, 9.47, 11.73 and 9.10 g/plant respectively. Similarly, Khater and Al-Azzony (2020) found that in relation to the impact of irrigation intervals on the weight of dried leaves per sweet basil plant, it was observed that irrigation intervals above 3 days, specifically 6 days, exhibited notable disparities when compared to the 9-day irrigation intervals in both cuttings of the tested seasons.

Data in Table 5 show that, different potassium silicate foliar application at the rate 2g/l (once or twice per cut for every season) significantly increased the dry weight of leaves per plant compared to the control (without spray). The best results in this regard (12.99 and 8.83 as well as 11.03 and 8.67 g/ plant) were recorded with the treatment of KS_3 (spraying twice with the rate 2g/l) per cut for every season, respectively. In this regard, Abd El-Razik *et al.* (2015) demonstrated that chervil plant vegetative development was increased by spraying potassium silicate twice before every harvest at a concentration of 1000 ppm. Additionally, Shehata and Sarhan (2023) discovered that the foliar treatments of 2000 ppm potassium silicate combined with 6 tons compost manure per hectare of sweet basil plants produced the most significant levels of vegetative growth.

As shown in Table 5 that irrigated French basil plants with 100%WR and spraying twice with 2g/l of KS per cut for every season gave a high increase in leaves' dry weight per plant compared to the other interaction treatments. Under any irrigation rate increasing potassium silicate rates gradually increased leaves dry weight per plant in both cut during first and second seasons. Furthermore, by making *Trachyspermum ammi* leaves and stems more erect and reducing mutuality shading, silicon deposition in the cell wall can make *Trachyspermum ammi* plants taller. This increases the rate of photosynthesis in the plant due to improved high interception and vegetative improvement growth (Sarhan and Shehata, 2023).

Water Use Efficiency

As shown in Figure (1) increasing the irrigation rate from 80 to 100 or 120% of WR under each potassium silicate application gradually decreased water use efficiency in the two cuts during 2021 and 2022 seasons. Furthermore, plants irrigated with 80% of WR combined with KS at 2g/l as twice/ cut in both seasons recorded the highest values of water use efficiency compared to the other interaction treatments under study.

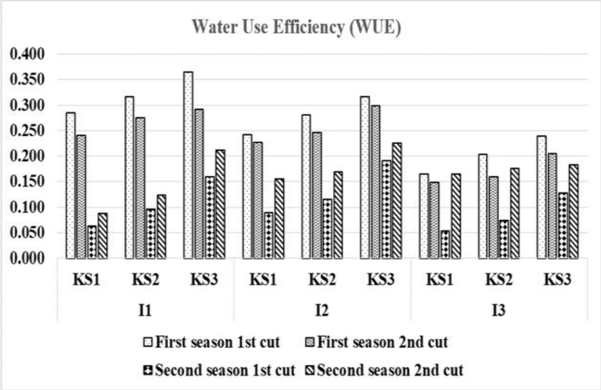

Fig. 1. Effect of interaction treatments between different irrigation rates and foliar application on water use efficiency of French basil (*Ocimum basilicum*) plant during 2021 and 2022 seasons, where I_1 (80%WR), I_2 (100%WR), I_3 (120%WR), KS_1 (without spray), KS_2 (spray once), KS3 (spray twice).

Simultaneously, Pejic *et al*. (2017) studied the effect of drip irrigation on water productivity of sweet basil (*Ocimum basilicum* L.) and found that the value irrigation water use efficiency (I WUE) at 431 mm in non-irrigated was 1.89 kg/m^3. Furthermore, Amer *et al*. (2019) discovered that the utilization of raised spearmint beds, along with 80% of the applied irrigation water, resulted in the highest water use efficiency (WUE) compared to the usual method employing 120% of the evapotranspiration rate (ETo). Specifically, the WUE values for the first and second seasons were determined to be 36.14% and 48.38%, respectively. Also, Serag El-Din and Mokhtar (2020) studied the impact of different irrigation rates (50, 75, 100 % of crop evapotranspiration) and some anti-transpirants (kaolin, $MgCO_3$, liquid paraffin and bentonite) on the water use efficiency and productivity of spearmint (*Mentha viridis* L.). They found that the treatment of 75% of ETc and the anti-transpirant treatment of $MgCO_3$ were the best combination for achieving the highest water use efficiency.

Chemical Composition of Leaves

Mineral content (N, P and K %)

From the same Tables 6 and 7, Data clear that the percentage of nitrogen, phosphorus and potassium significantly increased with increasing the rate of drip irrigation from I_1 to I_3, as the treatment of I_3 (12%WR) recorded (2.30, 2.29, 3.87 and 3.79 N%), (0.49, 0.48, 0.55 and 0.54 P %) and (3.88, 3.87, 2.99 and 3.01 K %). These results indicate the importance of the suitable level of drip irrigation in enhancing the leaves' mineral content of (N, P and K %) for basil plants. At the same trend, Asgharipour and Maspour (2016) reported that, water stress significantly decreased the concentration of calcium and potassium in fennel. Furthermore, there was a decline in the process of Nitrogen assimilation and the amount of water present in the cells due to a decrease in the absorption of water (Sarker and Oba, 2018). Because of the greater time-averaged water content in the soil, increasing irrigation volumes have a beneficial influence on the uptake of dissolved nutrients by sweet pepper plant leaf. This result is explained by the boosting effect of irrigation on the mass flow of dissolved nutrients (Silber, 2005). Furthermore, the right amount of moisture in plants promotes photosynthesis and the translocation of metabolites in sweet pepper, which quickens the rate at which nutrients are, absorbed (Ezzo *et al*., 2010).

Table 6. Effect of different irrigation rates (I) and foliar application of potassium silicate (KS) on nitrogen and phosphorus percentages of French basil during the two seasons (2021 and 2022)

Treatments		Nitrogen %				Phosphorus %			
		First season		Second season		First season		Second season	
		1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Effect of drip irrigation rates									
I_1		1.36c	1.34c	2.26c	2.22c	0.26c	0.25c	0.26c	0.25c
I_2		1.97b	1.96b	3.032b	2.97b	0.34b	0.33b	0.36b	0.35b
I_3		2.30a	2.29a	3.87a	3.79a	0.49a	0.48a	0.55a	0.54a
Effect of potassium silicate									
KS_1		1.70c	1.68c	2.66c	2.61c	0.33c	0.32c	0.32c	0.31c
KS_2		1.90b	1.89b	3.00b	2.95b	0.36b	0.35b	0.40b	0.39b
KS_3		2.03a	2.00a	3.49a	3.43a	0.39a	0.38a	0.45a	0.44a
Effect of the interaction treatments									
	KS_1	1.23g	1.22f	1.70g	1.67g	0.22g	0.21g	0.23i	0.22h
I_1	KS_2	1.36f	1.35ef	2.30f	2.26f	0.27f	0.26f	0.26h	0.25g
	KS_3	1.49e	1.45e	2.77e	2.72e	0.29e	0.29e	0.30g	0.30f
	KS_1	1.63d	1.61d	2.90e	2.84e	0.30e	0.30e	0.32f	0.31f
I_2	KS_2	2.08c	2.07c	3.00de	2.94de	0.34d	0.33d	0.37e	0.36e
	KS_3	2.20bc	2.19bc	3.19cd	3.14cd	0.37c	0.36c	0.40d	0.39d
	KS_1	2.23b	2.22b	3.38c	3.32c	0.47b	0.46b	0.42c	0.41c
I3	KS_2	2.27b	2.26b	3.70b	3.63b	0.48b	0.47b	0.58b	0.57b
	KS_3	2.39a	2.39a	4.52a	4.44a	0.51a	0.51a	0.66a	0.65a

Means having the same letter (s) in a column are not significant at 5% level, where I_1= 80%WR, I_2= 100%WR, I_3= 120%WR, KS_1 (g/l) = without spray, KS_2 (g/l) = spray once, KS_3 (g/l) = spray twice.

Applying potassium silicate as foliar application significantly increased the leaf content of N, P, K% (Tables 6 and 7) compared to the control (without foliar application) in the two cuts of both seasons and the best treatment was from spraying twice at the concentration 2g/l. In the same line, Shehata and Sarhan (2023) pointed out that the most significant levels of chemical components were formed when 6 tons of compost manure were applied to each hectare of sweet basil plants together with foliar applications of potassium silicate at 2000 ppm.

All interaction treatments between irrigation rates and for 2g/l of KS per cut for every season caused an improvement in total nitrogen percentage compared to 80 % WR + un-sprayed plants (Tables 6 and 7). Also, the total nitrogen, phosphorus and potassium percentages produced the highest values as a result of the combination treatments between the irrigation rate I_3 (120% WR) and spraying twice with potassium silicate (KS_3) at the rate 2g/l compared to the other interaction treatments. As mentioned just before, both irrigation treatments and spraying twice with potassium silicate at the rate 2g KS /l (each alone) increased mineral contents of NPK %, in turn, they together might maximize their effects leading to more N, P and K contents in leaves of basil plants.

Total Chlorophyll (mg/g F.W.)

Table 7 demonstrates that the irrigation rate treatments of 100% and 120% water requirement (WR) had a notable impact on the total chlorophyll a + b content of French basil leaves, as compared to the rate 80% WR, in both cuts throughout the two seasons. Additionally, the chlorophyll a + b content reached its high levels of 0.21 and 0.21 mg/g as fresh weight in both cuts during every season, when the plants were subjected to 120% water requirment. In this trend, Radácsi *et al*. (2020) conducted a study to examine the impact of irrigation on four different cultivars of sweet basil (*Ocimum basilicum* L.) in an open-field experiment. They implemented both irrigated and non-irrigated treatments and assessed the chlorophyll content. The chlorophyll content showed slight changes, as reported.

Table 7. Effect of different irrigation rates (I) and foliar application of potassium silicate (KS) on potassium percentage and total chlorophyll content (mg/g F.W.) of French basil during the two seasons (2021 and 2022)

Treatments		Potassium %				Total chlorophyll content (mg/g F.W.)			
		First season		Second season		First season		Second season	
		1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Effect of drip irrigation rates									
I_1		3.24c	3.24c	1.95c	1.93c	0.13c	0.13c	0.12c	0.12c
I_2		3.64b	3.62b	2.56b	2.56b	0.18b	0.18b	0.17b	0.17b
I_3		3.88a	3.87a	2.99a	3.01a	0.21a	0.21a	0.21a	0.21a
Effect of potassium silicate									
KS_1		3.50c	3.49c	2.23c	2.23c	0.16c	0.16c	0.15c	0.15c
KS_2		3.54b	3.53b	2.55b	2.55b	0.17b	0.17b	0.17b	0.17b
KS_3		3.72a	3.71a	2.71a	2.79a	0.19a	0.19a	0.18a	0.18a
Effect of the interaction treatments									
	KS_1	3.19h	3.19g	1.36g	1.35e	0.12g	0.11h	0.10h	0.10g
I_1	KS_2	3.23g	3.22f	2.15f	2.14d	0.13fg	0.13g	0.12g	0.12f
	KS_3	3.31f	3.30e	2.34e	2.30d	0.14ef	0.14f	0.14f	0.13e
	KS_1	3.59e	3.58d	2.42e	2.40d	0.17de	0.16e	0.16e	0.16d
I_2	KS_2	3.65d	3.64c	2.51d	2.50cd	0.18cd	0.18d	0.17d	0.17c
	KS_3	3.66d	3.65c	2.74c	2.79bc	0.19bc	0.20c	0.19c	0.19b
	KS_1	3.72c	3.71b	2.92b	2.93ab	0.21ab	0.20bc	0.20c	0.20b
I3	KS_2	3.74b	3.73b	2.99ab	3.00ab	0.21ab	0.21b	0.21b	0.21a
	KS_3	4.18a	4.17a	3.06a	3.27a	0.22a	0.22a	0.22a	0.21a

Means having the same letter (s) in a column are not significant at 5% level, where I_1= 80%WR, I_2= 100%WR, I_3= 120%WR, KS_1 (g/l) = without spray, KS_2 (g/l) = spray once, KS_3 (g/l) = spray twice.

The findings shown in Table 7 indicate that the application of 2 g/l of potassium silicate per cut in each season resulted in a significant increase in the total chlorophyll a + b content in the leaves of French basil. This increase was observed in both seasons, and it was higher compared to the other treatments.

The interaction effect analysis revealed that the total chlorophyll a + b content of *Ocimum basilicum* significantly recorded the highest values (0.22, 0.22, 0.22 and 0.21 mg/g as fresh weight) when subjected to the irrigation rate treatment of 120% WR combined with spraying twice at the rate 2 g/l of potassium silicate per cut for every season. This enhancement was observed in comparison to other interaction combinations in both cuts across the two seasons (Table 7). Simultaneously, all interaction treatments significantly increased the overall chlorophyll content compared to the rate 80% water requirement + without potassium silicate application. Simultaneously, Farouk *et al.* (2020) conducted a study to examine the impact of different methods of silicon (Si) application (foliar spraying, soil additive, or a combination of both) on sweet basil (*Ocimum basilicum* L.) plants cultivated under conditions of salinity stress. The researchers discovered that the application of Si using these methods resulted in a reduction of the detrimental effects of salinity on sweet basil, particularly in terms of biomass and phytopharmaceutical production.

Essential Oil Production and analysis:

Essential oil %

Data of both seasons in Table (8) indicate that increasing irrigation rates from 80 % WR to 100 % or 120% of WR significantly increased essential oil percentage in the two cuts during both seasons. The increases in essential oil percentage were 0.32 and 0.32 as well as 0.23 and 0.19 % for 100% WR irrigation rate 0.16 and 0.17 as well as 0.06 and 0.06 % for 120% WR irrigation rate over the lowest one (80% WR) in both cuts during each season, respectively. In this regard, Marino *et al.* (2019) pointed out that water stress had a detrimental impact on the essential oil yield of spearmint plants. This was attributed to a decrease in crop growth, specifically in terms of total and leaf biomass as well as crop growth. Also, Jat *et al.* (2023) demonstrated that the highest oil content of mentha (*Mentha arvensis*) was recorded with

75% cumulative pan evaporation (CPE). Moreover, drip irrigation at 125% CPE recorded the maximum oil yield.

From the obtained data in Table 8, it is evident that spraying French basil plants with potassium silicate at 2g/l two times /cut every season significantly increased essential oil % compared to the control (without spraying) and the others under the study in both cuts during 2021 and 2022 seasons. In general, both potassium silicate application times at the rate 2g/l (once or twice times) significantly increased essential oil percentage compared to the control (without spraying). In this trend, Waly *et al*. (2020) suggested foliar application of potassium silicate at 12 ml/l for a significant effect on percentage of essential oil and the GLC of essential oil of *Thymus vulgaris* plant compared with control (without spraying).

Moreover, the results under discussion reveal that the highest values in essential oil % were obtained by the treatment of 100% WR irrigation rate combined with twice potassium silicate foliar application per cut during the two seasons compared to the other combination treatments. In most cases, all combination treatments significantly increased essential oil percentage compared to the treatment (80 % WR + without potassium silicate foliar application) in the two cuts during both seasons. In a study conducted by Abd El-Razik *et al.* (2015), it was demonstrated that the application of potassium silicate had an inhibitory effect on transpiration and mitigated the negative impact of water stress on the development and essential oil yield of chervil plants. According to Farahani *et al*. (2021 a) on Rose plant found that both treatments: the foliar application of 0.4% potassium silicate under 50% of plant water requirements and the treatment of the foliar application 0.2% of potassium silicate under 25% of the plant water requirements produced the highest amounts of essential oil yield.

Table 8. Effect of different irrigation rates (I) and foliar application of potassium silicate (KS) on the essential oil percent (%) of French basil during the (2021 and 2022) seasons

Treatments		Essential oil (%)			
		First season		Second season	
		1st cut	2nd cut	1st cut	2nd cut
Effect of drip irrigation rates					
I_1		0.39c	0.39c	0.39c	0.40c
I_2		0.71a	0.71a	0.62a	0.59a
I_3		0.55b	0.56b	0.45b	0.46b
Effect of potassium silicate					
KS_1		0.50c	0.50c	0.43c	0.44c
KS_2		0.55b	0.56b	0.45b	0.46b
KS_3		0.60a	0.60a	0.58a	0.56a
Effect of the interaction treatments					
I_1	KS_1	0.34f	0.33f	0.36d	0.37e
	KS_2	0.41e	0.42e	0.41c	0.41d
	KS_3	0.42e	0.43e	0.41c	0.42cd
I_2	KS_1	0.64c	0.64c	0.51b	0.52b
	KS_2	0.73b	0.73b	0.52b	0.52b
	KS_3	0.75a	0.75a	0.82a	0.73a
I3	KS_1	0.52d	0.52d	0.42c	0.42d
	KS_2	0.51d	0.53d	0.42c	0.44c
	KS_3	0.62c	0.63c	0.51b	0.52b

Means having the same letter (s) in a column are not significant at 5% level, where I_1= 80%WR, I_2= 100%WR, I_3= 120%WR, KS_1 (g/l) = without spray, KS_2 (g/l) = spray once, KS_3 (g/l) = spray twice.

Essential oil composition

The data in (Table 9) show the comparisons among the major components of French basil essential oil as affected by irrigation rates combined with potassium silicate foliar application. It is indicated that the percentage of the main component Linalool (28.38%) was the highest with the treatment of 80%WR combined with spraying twice of potassium silicate (KS_3), while Caryphellen was the minimum with all combination treatments, in most cases.

Table 9. Effect of combination between different irrigation rates (I) and foliar application of potassium silicate (KS) on the percentage of major components of French basil essential oil at the first cut during the second season (2022)

Compound name	Essential oil components (%)								
	I_1			I_2			I_3		
	KS_1	KS_2	KS_3	KS_1	KS_2	KS_3	KS_1	KS_2	KS_3
α-pinene	0.26	0.50	1.04	0.95	0.76	1.1	0.26	0.52	0.53
α-myrcene	1.46	0.40	2.10	0.92	0.39	0.53	0.60	1.21	0.91
Eucalyptol	6.76	7.78	8.79	9.83	19.45	20.6	25.24	23.86	11.25
c-terpinene	0.80	0.84	0.96	0.25	0.26	0.30	0.46	0.44	0.43
Linalool	13.39	20.67	28.38	9.78	15.43	22.1	10.70	10.98	10.99
Camphor	1.47	0.34	1.56	1.00	0.95	1.13	0.64	0.42	1.87
Terbinene-4-ol	2.42	2.43	2.45	2.29	2.46	1.64	1.49	1.52	1.89
α-terpinol	4.99	5.45	6.13	5.05	5.03	5.40	0.46	0.44	0.42
Geraniol	0.60	3.45	4.36	0.42	0.40	0.14	0.28	0.22	0.21
Bronyl acetate	4.62	0.79	4.47	3.13	2.71	1.97	2.20	2.10	2.59
Eugenol	2.17	3.12	5.13	1.99	2.00	2.52	2.82	2.26	2.60
Caryphellen	0.72	0.75	0.95	0.67	0.41	0.30	0.39	0.39	0.35
Phenol	0.18	3.35	4.36	3.21	2.36	2.52	0.03	1.06	1.08
Naphthalene	3.03	0.8	2.58	3.3	3.16	1.98	2.34	1.86	3.15
Tau-Cadinol	3.15	7.00	1.74	2.28	1.69	0.94	1.18	1.17	2.37
Ester	2.10	2.3	0.60	1.10	1.48	0.91	1.00	0.97	0.87
Bergamotene	3.78	2.11	0.03	6.81	7.27	4.45	4.54	4.33	6.21
Methyl stearate	0.45	2.50	2.52	0.16	0.15	0.14	0.14	0.34	0.20
Known	52.35	64.58	78.15	53.14	66.36	68.67	54.77	54.09	47.92

I_1= 80%WR, I_2= 100%WR, I_3= 120%WR, KS_1 (g/l) = without spray, KS_2 (g/l) = spray once, KS_3 (g/l) = spray twice.

According to Radácsi *et al.* (2020), irrigation enhanced the essential oil yield of sweet basil by 40–129% depending on the cultivar but had a detrimental impact on glandular hair density and essential oil content, the essential oil of cultivar 'Kasia' only showed a significant compositional alteration for the ratios of linalool, 1,8-cineole, and taucadinole. Also, Waly *et al*. (2020) concluded that, the major essential oil components in *Thymus vulgaris* plants; α–pinene, α–terpinene, camphene, limonene, p-cymene, terpineolene, α-terpinene, borneol, carvacrol and thymol were affected under foliar application of potassium silicate. In addition, Farahani *et al*. (2021 b) discovered that the concentration of acyclic monoterpenoid alcohol molecules, such as citronellol acetate, citronellol, eugenol and geraniol increased in response to both Si nutrition and water shortage stress, altering the composition of the damask rose's blossom essential oil.

CONCLUSIONS AND RECOMMENDATION

It could be concluded that potassium silicate foliar application significantly increased French basil growth and essential oil percentage under drip irrigation in old land (Dakahlia Governorate). Moreover, it improved the quality of the volatile oil (the major component linalool was increased under 80% of water requirements). Thus, K-silicate foliar application improved water use efficiency under different irrigation rates. So, it could be recommended with potassium silicate foliar application at the rate of 2g/L for improving French basil productivity and essential oil quality under different irrigation rates in clay soil.

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تأثير معدلات الري بالتنقيط المختلفة والرش بسيليكات البوتاسيوم على النمو وإنتاج الزيت العطري لنبات الريحان الفرنسي

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الملخص

أجريت تجربة حقلية في مزرعة خاصة بقرية جديلة بمدينة المنصورة بمحافظة الدقهلية بمصر خلال موسمي الصيف لعامى 2021 و 2022 تحت ظروف التربة الطينية. كان الهدف من هذا البحث هو دراسة تأثير معدلات الري بالتنقيط (80 و 100 و 120% من الإحتياجات المائية للمحصول) والرش الورقي بسيليكات البوتاسيوم (بدون أو مرة واحدة أو مرتين بمعدل 2 جم/ لتر) ومعاملات التداخل بينهما على بعض صفات النمو الخضري (إرتفاع النبات ووزن الأوراق الجافة لكل نبات) و كفاءة إستخدام الماء والمحتوى المعدني من العناصر الكبرى (النتروجين والفسفور والبوتاسيوم) والمحتوى الكلي من الكلورفيل في الأوراق والمحتوى من الزيت العطري وتركيبه لنبات الريحان الفرنسي وقد أوضحت النتائج التي تم الحصول عليها أن ري نباتات الريحان الفرنسي بمعدل 120% من الإحتاجات المائية و/أورشه مرتين لكل حشة خلال موسم النمو بسليكات البوتاسيوم بمعدل 2 جم/لتر أعطي أطول النباتات وأعلى نسبة من المحتوى المعدني للعناصر الكبرى (النتروجين والفسفوروالبوتاسيوم) وكذلك المحتوى الكلي للكلورفيل في الأوراق بينما الري بمعدل 100% من الإحتياجات المائية مع الرش بمعدل 2جم/لتر من سليكات البوتاسيوم أعطى أثقل وزن للأوراق الجافة و أعلى نسبة للزيت العطري وحقق معدل الري بالتنقيط (80% من الإحتياجات المائية) مع الرش مرتين بسليكات البوتاسيوم بمعدل 2جم/لتر أفضل كفاءة لإستخدام الماء (WUE) .علاوة على ذلك كشف التحليل الكروماتوجرافي GC-MS أن المكون الرئيسي للزيت العطري في نباتات الريحان الفرنسي هو الليناالول وتم إستنتاج أن لسليكات البوتاسيوم تأثير في تحسين تراكم الكلورفيل وزيادة الوزن الجاف للأوراق وإنتاج الزيت العطري تحت معدلات الري المختلفة (80 و 100 و120 % من الإحتياجات المائية للنبات).