Effect of Water Stress and Salicylic Acid on the Growth and Oil Yield of *Ocimum basilicum* L. Plant in Newly Reclaimed Land

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ABSTRACT

The present study was carried- out during the two successive seasons of 2017 and 2018 at Banger AL-Sokar region, Borg AL-Arab, Alexandria, Egypt to study the effect of water stress, salicylic acid and irrigation rate on vegetative growth and oil yield of *Ocimum basilicum* L. plant in newly reclaimed land. Three levels of water stress were determined as a percentage of field water capacity 100, 75 and 50% and four concentrations of salicylic acid (SA) as foliar spray 0, 0.1, 0.2, and 0.4 mM were used, as well as two irrigation interval rates (every 4th and 7th days were applied. The results showed that spraying SA with low concentration i.e., 0.1- 0.4 mM led to improve the vegetative growth and oil yield of sweet basil plants under water stress. The highest oil yield (7.38%) was achieved at 75% of field capacity in second cut in the second seasons with spraying of SA at 0.2 mM irrigated every 4 days as a moderate stress.

Key words: Medicinal and aromatic plants, ornamental plants, basil, *Ocimum basilicum*, drought tolerance, drought stress, irrigation interval rate, salicylic acid, essential oil.

INTRODUCTION

Aromatic plants provide a sustainable source of flavoring ingredients for the food, perfumery, and pharmaceutical sectors (Gharib, 2006). Basil (*Ocimum basilicum* L.) is a member of the Lamiaceae family that is used as a spice, a medicinal herb, and a fresh vegetable (Farzane *et al.*, 2011). Most pharmacopoeias have included it as a medicinal plant. *Ocimum basilicum* includes essence, which is utilized in the treatment of certain ailments as well as in the food, cosmetics, and perfume sectors. Its essence is antibacterial and antifungal, and it repels insects (Hassani *et al.,* 2004).

Ocimum basilicum L. includes between 50 to 150 species of herbs and shrubs. Basil is native to the tropical regions of Asia, Africa and Central and South America (Gill and Randhawa,1997). There are a great variability of both morphology and chemo types of basil; it is an annual herb with 50-60 cm plant height having leaves of color form green to purple with small white or pink flowers (Sharafzadeh *et al.,* 2011).

Pripdeevech *et al.* (2010) reported that the dominant components of essential oil of basil were methyl chavicol (81.82 %), β-(E)-Ocimene (2.93%), α-(E)-bergamotene (2.45%), α-epicadinol (2.08%), 1,8-cineole (1.62%), methyl eugenol (1.10%), and camphor (1.09%). In the field experiment that was conducted to assess yield, oil content, and composition of 38 genotypes of *O. basilicum*, the availability of various chemotypes or individual compounds such as linalool, eugenol, methyl chavicol (estragole), methyl cinnamate, or methyl eugenol offersthe opportunity for production of basil was determined to meet the market requirements of specific basil oils.

In the last decades there has been a great interest in the adoption of water saving strategies in horticulture, due to the competition for water resources with other sectors and water scarcity (FAO, 2002). In fact, water is one of the most considerable compounds on the ground and 2/3 of the ground-level was surrounded by water, but in the most part of the world, lack of water is a critical factor which affects the production of the agricultural products.

One of the techniques used to increase plant tolerance to stress and alleviate the problem is using salicylic acid (SA) as a foliar spraying. It is white powder dissolves in water with a molecular formula of $C_7H_6O_3$. Salicylic acid is an endogenous phenolic compound produced by root cells in a large number of plants, and it plays a variety of roles in plant growth and development as a para-hormonal substance that regulates a variety of physiological processes in plants (Shakirova *et al.*, 2003), including plant growth and development, ion uptake, photosynthesis, germination, and defensive responses (Miura and Tada, 2014). It's thought to act as a natural thermogenesis indicator inducing flowering in many plants and controlling ion uptake by roots and stomata transmission (Raskin *et al.*, 1992). Plants' physiological and biochemical traits are also regulated when they are exposed to abiotic stress (Hashempour *et al.*, 2014).

Therefore spraying salicylic acid on plants can protect them against a variety of stresses. Many studies discussed the importance of salicylic acid and its effect as an antioxidant defense which has a regulatory role in promoting productivity on many plants via regulating cell division and photo protection regulation of

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photosynthesis and growth (Moradi & Rezvani, 2012; Hosseini *et al.*, 2015 and El-Deeb *et al.*, 2022).

The purpose of this study was to ascertain the impact of drought stress presented by irrigation intervals and the application of salicylic acid (SA) on the growth, and oil yield of *Ocimum basilicum* L. as it is one of the most important medicinal and aromatic plant.

MATERIALS AND METHODS

The present work was carried out during the two successive seasons of 2017/2018 at Banger AL-Sokar region, Borg AL-Arab, Alexandria, Egypt to study the effect of water stress, and salicylic acid on growth yield and chemical constitutes of essential oil of *Ocimum basilicum* L. plant in newly reclaimed land.

***Qcimum basilicum* plantation**:

Seeds of sweet basil (*Qcimum basilicum* L.) were supplied from the Horticulture Research Center, Dokki, Giza, Egypt. Seeds were sown on March, 15th 2017 and March, 30th 2018 in the first and second seasons, respectively, in sandy clay loam soil using seed pans. After one month from sowing and when the seedling reached 8-10 cm. Height with 6-8 leaves and 4 branches, they were transplanted to the final clay pots 30 cm diameter filled with a mixture of clay, sand and cattle manure (2:1:1 by volume). Physical and chemical properties of the media used (Tables 1 and 2) were analyzed at the unit of Analysis and Scientific Services Soil and Water Activity of Information, Services and Training at the Faculty of Agriculture, University of Alexandria, Egypt.

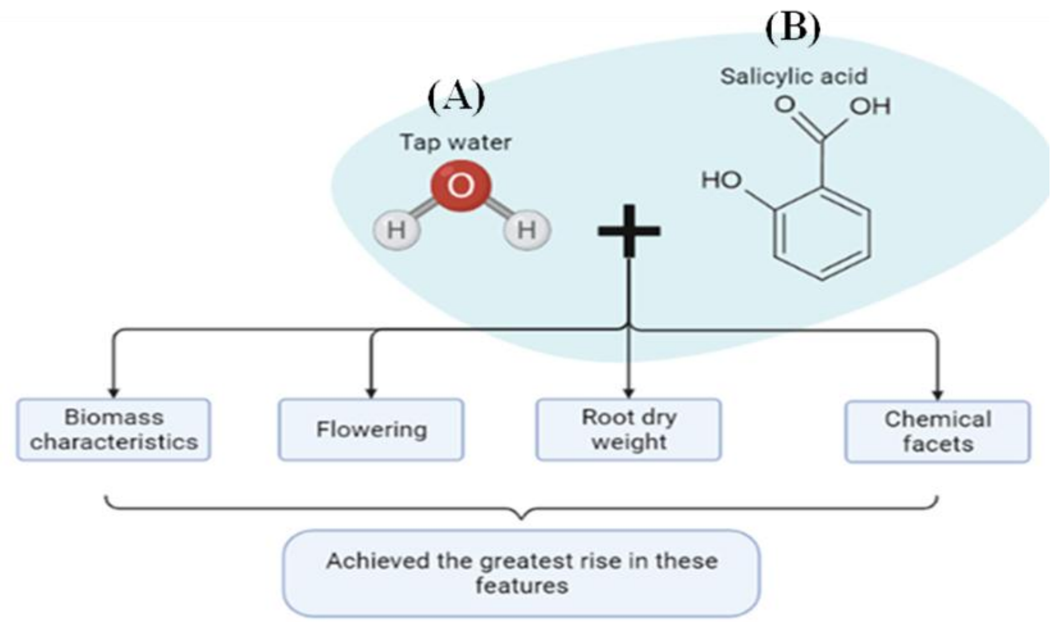
Seedlings were treated with three levels of water stress determined as a percentage of field water capacity (FWC) i.e., 100, 75 or 50% and four concentrations of salicylic acid (SA) as a foliar spray (SA) i.e., 0, 0.1, 0.2, or 0.4 mM and two irrigation interval rate (IIR) i.e., irrigation every 4th day or irrigation every 7th day (Scheme 1).

Table 1. Physical analysis of the growing media used in the current study

Clay (%)	Silt (%)	Sand (%)	Soil texture
25.54	7.70	66.76	Sandy clay loam

Table 2. Chemical analysis of the growing media used in the study

E.C. ($ds.m^{-1}$)	pH	Anions ($Meq.L^{-1}$)				Cations ($Meq.L^{-1}$)			
		CO_3^{2-}	HCO_3^-	CL^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}
7.00	7.74	--	20.5	44.0	5.5	10.0	7.6	37.5	15.0



(1) Schematic diagrams for the both factors (A) water stress (100 FC, 75% FC and 50%), (B) Salicylic acid (SA) (0-0.1-0.2 and 0.4 mM).

Experimental layout and statistical analysis:

The experiment layout was conducted to provide a split-split plot design containing three replicates. The main-plot was IIR and the sub-plot was FWC, while the SA was the sub-sub-plot, each replicate contained (3 FWC × 2IIR ×4 SA) treatments. Each experimental unit contained 5 plants (Snedecor and Cochran, 1990).

Morphological measurements:

The vegetative growth parameters were included plant height (cm), leaf number, and number of branches per plant.

Extraction of essential oil extraction:

The essential oil of Basil was extracted according to Novak *et al.* (2002) by using water distillation method. The fresh leaves from each plant were moved into the 2-L flask and the amount of water (about 4-6 times as much as the plant material) was added. A proper essential oil trap and condenser were attached to the flask. The distillation was continued until no further increase in the oil was observed (for about 45-60 minutes). The collected oil was kept dry in a sealed Eppendorf tubes at 4°C until GC/MS analysis.

The oil percentage was calculated according to Charles and Simon (1990) as a percentage of the weight of leave sample. The oil yield per plant was calculated by multiply the percentage of oil and the leaf fresh weight per plant.

RESULTS AND DISCUSSION

I- Impact of water stress, irrigation intervals, salicylic acid and their interactions on the vegetative growth of *Ocimum basilicum* L.

According to the data presented in Table (3), plants grown at 100% of field capacity typically reached the most extended heights of 46.71 and 51.71 cm in the two cuttings of the first season and 47.10 and 52.04 cm in the two cuttings of the second season. The plants that grown at 50% field capacity were the shortest. The tiny plants' of the 1st cuttings were 34.13 and 37.38 cm long, while the 2nd cuttings are 35.19 and 37.22 cm long. These results are similar to those obtained on *Salvia officinalis* (Corell *et al.*, 2012) and on *Salvia Hispanic* (Herman *et al.*, 2016).

Water stress causes stomata closure and decreases plant mineral uptake, which affects plant growth and may explain the shortening of plant height under soil moisture stress (El-Noemani *et al*, 2010). On the other hand, short irrigation interval (4 day) exceeded long interval (7 day) and significantly increased basil plant height by 45.09 and 49.17 cm in the two successive cuttings of the 1st season and 45.49 and 49.44 cm in the second season compared with seven days interval as shown in Table (3). Similar results were obtained on different crops by Jerez and Cartaya (2004) on *Ocimum basilicum* L. and Mohamad (2015) on *Catharanthus roseus.*

Where short irrigation intervals favor growth, extending irrigation intervals causes a progressive and constant increase in the osmotic pressure of the soil solution (Shao and Miri, 2013), which cause a decrease in the synthesis of metabolites, a reduction in the translocation of nutrients from the soil to the plant and within the plant, a decrease in cell division, and cell elongation. All of this probability could be considered the leading cause of depression in vegetative growth (Shao *et al.*, 2008). As for the concentration of SA, the obtained results were pointed out that 0.1 mM of SA produced the tallest plants in the two cuttings in both seasons of the study, however, there were no significant differences with 0.2 mM in the first cutting in the two seasons and with 0.2 and 0.4 mM concentrations in 2nd cutting in 2nd season. These findings were consistent with those of Gharib (2006) and Kordi *et al.* (2013) on *Ocimum basilicum*.

For the combinations of the two-way factors between each of water stress, irrigation intervals and SA (Table 4), the tallest basil plants in 2nd season was 55.54 cm and came from irrigation every four days at 100% field capacity, then irrigation every four days at 75% field capacity (52.95 cm). On the other hand, increasing the interval to 7 days under 50% field capacity resulted in the shortest plants (34.70 cm) in 2nd cutting during the second season.

Plants sprayed with 0.1% SA under 100% field capacity grew the tallest in two successive cuttings (50.67 and 55.67 cm) in the 1st season and (51.00 and 55.83 cm) in the 2nd season (Table 4). In contrast to 50% field capacity, plants often produced the shortest plants, mainly when no SA was applied or when 0.2 mM of SA was applied to the two cuttings in both seasons. These findings were consistent with those published by El-Mergawi and Abdel-Wahed (2003) on *Catharanthus roseus* and showed a substantial response on all growth parameters. In this study, a combination of modest SA dosages and 3-day irrigation produced significant increases in all growth parameters.

Nicola *et al.* (2008) reported that deficiency watering changed the morphology of rosemary plants where plant height is being reduced. Water deficiencies have been shown to reduce growth (Bettaieb *et al.*, 2009 and Ekren *et al.*, 2012).

According to the data in Table (3), the first and second cuttings of the first season were produced the most significant number of branches (26.63-32.54 branch) and (27.33-33.5) on the first and second cuttings of the second season on the 100% FC. The 50% of field capacity was provided the least number of branches per plant (17.69 and 21.29 cm branch) in the 1st season and (18.54 and 21.88cm branch) in the 2nd season. These findings are agreed with those of Stanhill & Albers (1974) and Banon *et al.* (2003). These developmental, morphological changes might be understood as a plant's morphological response to water and environmental difficulties to limit transpiration and encourage lower water consumption. Furthermore, lowering stomatal conductance and biomass from aerial portions may have a role in plant drought resistance (Diaz-Lopeza *et al.*, 2012). This finding is consistent with those of Yazdanpanah *et al.* (2011) and Hassan *et al.* (2013).

In contrast, the short watering interval (4 days) outperformed the long interval (7 days) and considerably increased the number of branches (22.88 and 27.58 branch) in the first season's two subsequent cuts and (23.86 and 28.44 branch) in the second season compared to the 7-day interval. The basil plant height and number of branches per plant dropped as the watering interval increased. These results are inagreement with those published by Leithy *et al.* (2006) on *Hordeum vulgarel*; Rao *et al.* (2005) and Metwally *et al.* (2018) on *Thymus valgaris*.

Short watering intervals promote growth at the same time, increasing watering intervals, resulting in a gradual and consistent increase the osmotic pressure of the soil solution rises which result in a drop in metabolite synthesis, a decrease in nutrient transfer from the soil to the plant and within the plant, and a reduction in cell division and elongation. All of this may be regarded as the primary cause of vegetative growth depression (Shao *et al.*, 2008). In terms of SA concentration, the results showed that 0.1 mM were generated the most branches in the two cuttings in both seasons of study. However, there were no significant differences with 0.2 mM and 0.4 mM in the 2nd cutting in the 2nd season (27.27- 27.00). These findings were similar to those reported by Karalija and Parić (2017), who found that foliar application of SA at rates of 0.01, 0.1, and 1.0 mM resulted in an increase in morphological traits and additional metabolites production in *Ocimum basilicum* and Gharib (2006) found that SA increased growth in terms of number of branches in both seasons.

The interaction of the three studied factors field capacity, irrigation intervals and salicylic acid revealed that irrigation every four days at 100% field capacity produced the most branches (39.32- 40.33) in the second cutting of the two seasons, followed by irrigation every four days at 75% field capacity (39.32-28); however, increasing the interval to 7 days under 50% field capacity produced the fewest branches (17-18) in the first cutting of the two seasons (Table 5).

Plants sprayed with 0.1 mM of SA at 100% field capacity generated the most branch numbers in the two cuttings (33.3 and 39.3 branch) and (34.0 and 40.33 branch) in the first and second season, respectively (Table 5). On the contrary, 50% field capacity generated the fewest branch numbers, mainly when no SA was applied. These findings were consistent with those published by El-Mergawi and Abdel-Wahed (2003) on *Catharanthus roseus* who showed a substantial response on all growth parameters. In basil, stomata conductance decreased in response to salt- stress conditions, which had an impact comparable to water stress (Attia *et al.*, 2011).

Drought stress might trigger the closure of stomata, while the uptake of CO_2 is blocked, the biosynthesis may shift in the direction of secondary metabolites and in parallel, the biomass production is most frequently reduced (Selmar & Kleinwächter, 2013 and Al-Gabbiesh *et al.*, 2015).

Salicylic acid operates at the transcription and/or translational levels by raising the activity of many other enzymes required for plant development (Hayat *et al.*, 2010). Furthermore, SA increases cell division and expansion (Hayat *et al.*, 2012).

According to Table (4) 100% field capacity generated the most leaves per plant (475.83 and 486.75 leaf) in the first and 2nd cuttings of the 1st season and (480.83 and 499 leaf) in the two subsequent cuttings of 2nd season. Conversely, 50% field capacity yielded the fewest leaves (240.74 and 246.25 leaf) in the first and second cuttings of the 1st season and (243.92 and 246.92 leaf) in the two subsequent cuttings of the 2nd season.

Under drought circumstances, the number of leaves per plant reduced due to the low turgor pressure, this might be associated to cell expansion and growth inhibition. The lower number of leaves produced by moisture stress is consistent with the findings of Stolf-Moreira *et al.* (2010), who reported that water stress reduced the number of leaves in soybeans. This is because water stress lowers the rate of leaf initiation and the leaf area of already-formed leaves. This may be due to decreased photosynthetic activity in the afflicted leaves. The overall consequence is a reduction in the rate of new leaf initiation and an increase in leaf shedding, resulting in a reduction in the number of green leaves per plant (Ghassemi *et al.*, 2019 and Yunusa *et al.*, 2019). Short watering intervals, on the other hand, had a substantial impact on the quantity of basil leaves. The 4-day watering interval treatment produced the most leaves numbers (408.44- 423.53

branch) and (411.58 - 428.75 branch) for the two plant cuttings in both seasons.

Irrigation at 7-day intervals, on the other hand, produced the fewest leaves (378.58 and -384.14 leaf) in the first season's two consecutive cuttings and (380.69 and -387.06 leaf) in the second season's two consecutive cuttings. Calatayed *et al.* (2002) achieved similar findings on different crops, as did Jerez and Cartaya (2004) on *Ocium basilicum* L. and Mohamad (2015) on *Catharanthus roseus*.

Extending watering intervals results in a gradual and consistent increase as well as the osmotic pressure of the soil solution is rises. These inhibit metabolite production, diminish nutrient transfer from the soil to the plant and within the plant, and reduce cell division and cell elongation. All of these may be regarded as the major cause of depression in vegetative development (Shao *et al.*, 2008). In terms of SA concentration, data showed that 0.1 mM generated the most leaves per plant in the two cuttings in both study seasons. There were no significant differences between the three values in the second cut of the 1st season and the 0.1- and 0.2 mM concentrations in the 1st and 2nd cuttings of the 2nd season. These findings matched those of Kordi *et al.* (2013) on *Ocimum basilicum*, Gharib (2006) on *Ocimum basilicum* and *Majorana hortensis*. Exogenous administration of SA, particularly at 0.1 mM, increased the growth features of both species, according to Hesami *et al.* (2012) on *Coriandrum sativum*.

The combination of the three elements investigated (field capacity, irrigation intervals, and salicylic acid) revealed that irrigation every 4 days at 100% field capacity generated the most leaves per plant in the 2nd cutting of the 2nd season. Irrigation every four days at 75% field capacity followed. Increasing the interval to 7 days under 50% field capacity, on the other hand, resulted in the lowest number of leaves per plant in the first cutting during the first season.

Treated plants with 0.1 mM of SA under 100% of field capacity generated most leaves in both seasons (Table 4). On the contrary, 50% of field capacity generated the fewest leaves per plant, particularly without salicylic acid treatment or with 0.1 mM SA in both cuttings across both seasons. These findings were consistent with those published by El-Mergawi and Abdel-Wahed (2003) on Catharanthus roseus and they showed a substantial response on all growth parameters. A combination of modest SA dosages and 3-day irrigation interval produced substantial increases in all growth parameters (Table 4). In addition, Nicola *et al.* (2008) reported that deficiency watering changed the morphology of rosemary plants where plant height is being reduced.

Table 3. Average of plant height (cm), number of branches (NOBs) and number of leaves (NOLs) of *Ocimum basilicum* plants as affected by each of water field capacity (WFC), irrigation rate (IIR) and salicylic acid (SAC) in the two cuttings for the two growing seasons

Treatment	1st Season						2nd Season					
	Plant height (cm)		NOBs		NOLs		Plant height (cm)		NOBs		NOLs	
WFC%	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**
100	46.71	51.71	26.6	32.5	475.8	486.8	47.10	52.04	27.33	33.50	480.8	499.0
75	43.61	48.08	20.1	25.1	459.1	478.5	43.65	48.70	21.46	25.87	463.7	477.8
50	34.13	37.38	17.7	21.3	240.7	246.3	35.19	37.22	18.54	21.87	243.9	246.9
$LSD_{0.05}$	**0.50**	**1.18**	**0.08**	**0.07**	**0.04**	**0.04**	**0.63**	**1.35**	**0.06**	**0.08**	**0.04**	**0.05**
IIR (day)	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**
4	45.09	49.17	22.9	27.6	408.4	423.5	45.49	49.44	23.86	28.44	411.6	428.8
7	38.22	42.28	20.3	25.0	378.6	384.1	38.47	42.54	21.03	25.72	380.7	387.1
$LSD_{0.05}$	**0.69**	**0.60**	**0.07**	**0.08**	**0.03**	**0.06**	**0.73**	**0.73**	**0.04**	**0.08**	**0.03**	**0.06**
SAC (mM)	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**
Control	39.39	43.39	20.8	25.6	389.1	398.2	39.78	43.58	21.39	25.94	391.7	401.9
0.1	43.67	47.72	22.5	27.2	395.2	405.1	43.56	47.83	23.39	28.11	399.1	411.7
0.2	42.11	46.17	21.4	26.5	392.8	406.	43.0	46.30	22.66	27.27	398.6	410.6
0.4	41.00	45.61	21.6	25.9	395.5	405.7	41.58	46.25	22.33	27.00	395.2	407.4
$LSD_{0.05}$	**1.04**	**1.09**	**0.07**	**0.06**	**0.03**	**0.05**	**1.24**	**1.17**	**0.15**	**0.10**	**0.02**	**0.03**

LSD0.05 is the least significant difference at 5% level of probability.

Table 4. Mean values of plant height (cm), number of branches (NOBs) and number of leaves (NOLs) of *Ocimum basilicum* plants affected by water field capacity (WFC), irrigation interval rates (IIR) and salicylic acid concentrations (SAC) in the two cuttings for both growing seasons

	1^{st} Season						2^{nd} Season					
	Plant height (cm)		Number of branches		Number of leaves		Plant height (cm)		Number of branches		Number of leaves	
Water × day	**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**
100% × 4d	50.25	55.25	29.00	35.00	494.17	509.17	50.75	55.62	29.91	36.17	501.17	529.5
100% ×7d	43.17	48.17	24.25	30.08	457.50	464.34	43.46	48.46	24.75	30.83	460.50	468.5
75%×4d.	47.45	51.92	21.00	25.83	476.82	506.75	47.08	52.96	22.58	26.75	482.17	501.17
75% ×7d.	40.08	44.25	19.33	24.33	442.83	450.25	40.21	44.46	20.33	25.00	445.17	454.42
50%×4d.	37.09	40.33	18.09	21.92	246.55	254.67	38.63	39.75	19.08	22.42	251.42	255.58
50% ×7d.	31.42	34.42	17.33	20.66	235.42	237.85	31.75	34.71	18.00	21.33	236.42	238.12
LSD$_{0.05}$	NS	1.058	0.091	0.094	0.037	0.064	NS	1.233	NS	0.096	0.046	0.071
Day × SA	**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**
4 d. × 0.0	42.00	46.00	21.88	26.67	403.56	416.11	42.56	46.17	22.67	27.11	407.22	422.22
4 d. × 0.1	47.78	51.77	24.00	29.00	408.89	423.11	47.67	52.11	25.33	30.00	414.33	433.22
4 d. × 0.2	46.00	50.00	22.66	27.66	406.11	428.44	47.22	49.72	24.00	28.56	415.00	433.11
4 d. × 0.4	44.43	48.89	23.00	27.00	417.14	426.42	44.50	49.78	23.44	28.11	409.78	426.44
7 d.×0.0	36.78	40.78	19.66	24.44	374.56	380.3	37.00	41.00	20.11	24.78	376.11	381.67
7 d.×0.1	39.56	43.67	20.88	2534	381.56	387.12	39.44	43.56	21.44	26.22	383.89	390.11
7 d.×0.2	38.22	42.33	20.11	25.33	379.55	384.13	38.78	42.89	21.33	26.00	382.11	388
7 d.×0.4	38.33	42.33	20.56	24.85	378.67	385.00	38.67	42.72	21.22	25.89	380.67	388.44
LSD$_{0.05}$	NS	1.423	NS	0.099	Ns	0.076	NS	1.985	0.024	NS	NS	NS
Water × SA	**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**
100% × 0.0	43.83	48.83	25.33	31.22	471	482.17	44.25	49.08	26.17	31.83	474.83	491.5
100% ×0.1	50.67	55.67	29.33	35.33	484.67	493.32	51.00	55.83	29.83	36.17	490.50	511.00
100% × 0.2	47.16	52.16	26	31.73	475.33	486.67	47.50	52.50	26.83	33.17	480.83	498.33
100% × 0.4	45.17	50.10	25.83	31.57	472.33	484.84	45.67	50.58	26.50	32.83	477.17	495.17
75%× 0.0	41.66	45.67	19.66	24.55	456.17	467.83	42.00	46.00	20.50	25.00	458.83	470.5
75%× 0.1	44.83	49.00	20.83	25.50	459.83	476.5	44.50	49.58	21.67	26.00	464.00	478.17
75%× 0.2	45.66	49.83	20.5	26.33	465.16	485.5	45.08	49.92	22.50	26.83	471.00	486.83
75%× 0.4	43.00	47.83	19.33	23.63	457.17	484.17	43.00	49.33	21.17	25.67	460.83	475.67
50%× 0.0	32.67	35.60	17.33	20.56	240.00	244.67	33.08	35.67	17.50	21.00	241.33	243.83
50%× 0.1	35.50	38.50	17.16	20.83	241.83	245.50	35.17	37.92	18.67	22.17	242.83	245.83
50%× o.2	33.50	36.50	17.66	21.33	238.00	246.68	36.42	36.5	18.67	21.83	243.83	246.5
50%× o.4	35.83	38.83	18.67	22.35	245.83	248.16	36.08	38.83	19.33	22.50	247.67	251.5
LSD$_{0.05}$	1.604	1.683	0.006	0.006	0.001	0.003	2.200	1.552	0.180	0.132	0.041	0.063

LSD$_{0.05}$ is the least significant difference at 5% level of probability.
NS is not significant.

Table 5. Average of plant height (cm), number of branches and number of leaves of *Ocimum basilicum* plants as affected by the interaction between different water stress, irrigation intervals and salicylic acidin the twocuttings in the first and second growing seasons

Treat.			1st Season						2nd Season					
			Plant height (cm)		Number of branches		Number of leaves		Plant height (cm)		Number of branches		Number of leaves	
W.	D.	SA	1st Cut	2nd Cut	1st Cut	2nd Cut	1st Cut	2nd Cut	1st Cut	2nd Cut	1st Cut	2nd Cut	1st Cut	2nd Cut
100 %	4	0.0	46 .00	51.00	27.00	33.00	490.00	505.00	46.67	51.33	28.00	33.67	495.67	520.67
		0.1	56 .00	61.00	33.33	39.32	502.66	515.33	56.33	61.33	34.00	40.33	511.00	544.33
		0.2	51.00	56.00	27.67	33.67	494.00	509.00	51.33	56.33	29.00	35.33	501.33	529.67
		0.4	48 .00	53.00	28.00	34.00	490.00	507.30	48.67	53.50	28.67	35.33	496.67	523.33
	7	0.0	41.66	46.67	23.67	29. 64	452.00	459.32	41.83	46.83	24.33	30.00	454.00	462.33
		0.1	45.33	50.34	25.32	31.32	466.67	471.22	45.67	50.67	25.67	32.00	470.00	477.66
		0.2	40.00	48.33	24.33	30.00	456.66	464.12	43.67	48.67	24.67	31.00	460.33	460
		0.4	42.23	47.32	23.66	29.33	454.67	462.33	42.66	47.67	24.33	30.33	457.67	467
75%	4	0.0	44.67	48.67	20.66	25.67	474.00	489.67	45.17	49.16	21.67	26.00	477.67	494.33
		0.1	48.66	52.69	21.32	26.31	476.33	500.33	48.33	54.16	22.67	27.00	482.00	501.33
		0.2	50.66	54.66	22.33	27.34	483.33	520.66	49.33	54.5	24.00	28.00	492.00	513.67
		0.4	45.00	51.66	19.00	24.00	472.00	516.31	45.50	54.00	22.00	26.00	477.00	495.33
	7	0.0	38.67	42.63	18.66	23.66	438.33	446.00	38.83	42.83	19.33	24.00	440.00	446.67
		0.1	41.00	45.33	20.67	24.69	443.32	452.67	40.67	45.00	20.67	25.00	446.00	455.00
		0.2	40.67	45.00	18.67	25.32	447	450.32	40.83	45.33	21.00	25.67	450.00	460.00
		0.4	40.00	44.00	20.31	23.67	442.66	452.00	40.50	44.67	20.33	25.33	444.67	456.00
50%	4	0.0	35.33	38.22	18	21.33	246.67	253.67	35.83	38.00	18.33	21.67	248.33	251.60
		0.1	38.65	41.67	17.31	21.33	247.66	253.66	38.33	40.83	19.33	22.67	250.00	254.00
		0.2	36.32	39.33	18.00	22.00	241.00	255.69	41.00	38.33	19.00	22.33	251.67	256.00
		0.4	38.50	42.00	19.67	23.00	253	255.67	39.33	41.83	19.67	23.00	255.67	260.67
	7	0.0	30.00	33.00	16.66	20.00	233.33	235.66	30.33	33.33	16.67	20.33	234.33	236.00
		0.1	32.33	35.32	17.00	20.22	234.66	237.31	32.00	35.00	18.00	21.67	235.67	237.67
		0.2	30.67	33.67	17.32	20.68	235.00	237.64	31.83	34.66	18.33	21.67	236.00	237.00
		0.4	32.66	35.67	18.33	21.69	238.67	240.66	32.83	35.83	19.00	22.00	239.67	242.33
$LSD_{0.05}$			2.344	2.540	0.165	0.162	0.075	0.121	NS	NS	0.313	NS	NS	NS

$LSD_{0.05}$ is the least significant difference at 5% level of probability.
NS is not significant.

II- Impact of water stress, irrigation rate, salicylic acidand their combinations on oil percentage and oil yield of *Ocimum basilicum* plants:

According to the analysis of variance, water field capacity, irrigation interval rates, and the salicylic acid concentrations in the two cuttings over the two seasons all had a significant influence on the oil percentage of basil leaves (Table 6 a,b,c). There was a significantly relationship between water field capacity and irrigation intervals. Table (6 a,b,c) showed that the 50% WFC was typically generated the greatest oil percentage on basil leaves (0.23 and 0.25%) in the two cuttings of the 1st season and (0.25 and 0.26%) in 2nd season's two subsequent cuttings. In the first and second cuttings of the first season, 100% field capacity generated the lowest oil percentage (0.14 and 0.15%) and (0.16 and 0.17%) in the two cuttings of the 2nd season. These were equivalent to those reported by

Yassen *et al.* (2003) and Khalid (2006). According to Arabaci & Bayram (2004); Telci *et al.* (2005); Khalid (2006) and Hassan *et al.* (2015), the essential oil ratio in plants is affected by a range of variables, with environmental influences having a minor impact.

Short watering intervals (4 days) raised the oil percentage of basil by 0.21 and 0.22% in the two subsequent cuts in 1st season and 0.23 and 0.24% in 2nd season, respectively. These were comparable to those reported by Metwally *et al.* (2018) compared to 7 days. The varying watering intervals affect the essential oil percentages.

Regarding salicylic acid concentration, data showed that 0.4 mM SA generated the maximum essential oil percentage on basil leaves in both research seasons (Table 6). These findings were consistent with findings of Gharib (2006) and might be regarded as effective on basil. As a result of the observed variance in the reported response from 0.1 mM to 1 mM and the greater SA levels among various plants, so we recommend integrating the complete dose range in the future investigations.

The interaction of the three studied factors (Table 7) revealed that the highest significant means in essential oil percentage in the first cut during the first season were observed mostly when plants were grown under 50% soil moisture level and irrigation intervals (4 days) and sprayed with 0.4 mM followed by 0.2 mM at the same level SA only during the vegetative stage. These findings were consistent with those published by Baher *et al.* (2002). Under 50% soil moisture, there was a rise in essential oil percentage (Hendawy & Khalid, 2005 and Al-Shukry & Abbas, 2016).

Data showed in Table (6) that the field capacity was 75%. They have consistently generated the maximum oil output on basil leaves (4.32 and 4.82) in the 1st and 2nd cuttings of the 1st season and (5.52 and 6.02) in the two subsequent cuttings of the 2nd season. In contrast, 100% field capacity provided the lowest oil yields (3.22 and 4.03) in the first and 2nd cuttings of the 1st season and (4.08 and 4.68) in 2nd season's two subsequent cuts. These findings were consistent with those reported by Khalid (2006). For both *Ocium* species, 75% of field water capacity gave the maximum essential oil output. Short watering intervals (4 days) boosted oil output by (4.32 and 4.95) in the first and second cuttings of the first season and (5.45 and 6.14) in the two subsequent cuttings of the second season. In comparison to 7 day period, in terms of SA concentration, data showed that 0.4 mM SA provided the best oil output on basil leaves in both research seasons. These findings were comparable to those published by Gharib (2006) and might be regarded as satisfactory for basil.

Table 6. Average values of oil percentage and oil yield per plant of the *Ocimum basilicum* plants as affected by each of the water field capacity (WFC), irrigation interval rates (IIR) and the salicylic acid concentration (SAC) in the two cuttings for both growing seasons

Treatment	1st Season				2nd Season			
	Oil percentage		Oil yield per plant		Oil percentage		Oil yield per plant	
WFC (%)	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**
100%	0.14	0.15	3.32	4.030	0.16	0.17	4.08	4.68
75%	0.21	0.21	4.32	4.824	0.23	0.23	5.52	6.02
50%	0.23	0.25	3.49	3.975	0.25	0.26	4.43	5.95
$LSD_{0.05}$	0.14	0.20	1.386	0.955	0.326	0.01	0.474	0.549
IIR (Day)	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**
4 days	0.21	0.22	4.32	4.95	0.23	0.24	5.45	6.14
7 days	0.18	0.19	3.12	3.6	0.19	0.20	3.90	4.96
$LSD_{0.05}$	0.03	0.16	1.179	0.388	0.08	0.01	0.198	0.304
SAC (mM)	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**
0.0	0.18	0.18	3.21	3.78	0.19	0.20	3.96	4.74
0.1	0.29	0.20	3.79	4.27	0.20	0.21	4.57	5.42
0.2	0.21	0.21	3.98	4.59	0.22	0.22	4.96	5.84
0.4	0.20	0.21	3.95	4.69	0.23	0.24	5.23	6.21
$LSD_{0.05}$	0.07	0.16	0.176	0.653	0.30	0.02	0.488	0.320

$LSD_{0.05}$ is the least significant difference at 5% level of probability, NS is not significant.

Table 6-a. Average of oil percentage and oil yield per plant of *Ocimum basilicum* plants as affected by water field capacity (WFC) and irrigation interval rates (IIR) in the two cuttings at the two growing seasons

WFC (%)	IIR (day)	1st Season				2nd Season			
		Oil Percentage		Oil yield per plant		Oil Percentage		Oil yield per plant	
		1st Cut	2nd Cut	1st Cut	2nd Cut	1st Cut	2nd Cut	1st Cut	2nd Cut
100	4	0.16	0.17	4.79	5.54	0.17	0.18	4.79	5.54
	7	0.13	0.14	3.38	3.81	0.15	0.15	3.38	3.81
75	4	0.22	0.22	6.40	6.92	0.24	0.24	6.40	6.92
	7	0.21	0.21	4.63	5.12	0.22	0.22	4.63	5.12
50	4	0.26	0.28	5.18	5.95	0.28	0.29	5.18	5.95
	7	0.21	0.22	3.68	5.95	0.22	0.22	3.68	5.95
$LSD_{0.05}$		**0.01**	**0.02**	**0.40**	**0.51**	**NS**	**0.04**	**0.40**	**0.51**

$LSD_{0.05}$ is the least significant difference at 5% level of probability, NS is not significant.

Table 6-b. Average of oil percentage and oil yield per plant of *Ocimum basilicum* plants as affected by water field capacity (WFC) and salicylic acid concentration (SAC) in the two cuttings at the two growing seasons

WC (%)	SAC (mM)	1st Season				2nd Season			
		Oil Percentage		Oil yield per plant		Oil Percentage		Oil yield per plant	
		1st Cut	2nd Cut	1st Cut	2nd Cut	1st Cut	2nd Cut	1st Cut	2nd Cut
100	Control	0.13	0.14	3.38	3.88	0.14	0.15	3.38	3.88
	0.1	0.15	0.16	4.13	4.83	0.16	0.17	4.13	4.83
	0.2	0.15	0.16	4.35	4.85	0.17	0.17	4.35	4.85
	0.4	0.16	0.17	4.49	5.15	0.18	0.19	4.49	5.15
75	Control	0.19	0.19	4.88	5.40	0.21	0.22	4.88	5.40
	0.1	0.22	0.21	5.56	5.80	0.23	0.22	5.56	5.80
	0.2	0.23	0.22	5.84	6.47	0.23	0.24	5.84	6.47
	0.4	0.23	0.23	5.80	6.42	0.24	0.25	5.80	6.42
50	Control	0.22	0.23	3.63	4.94	0.23	0.24	3.63	4.94
	0.1	0.24	0.25	4.02	5.63	0.23	0.25	4.02	5.63
	0.2	0.25	0.26	4.69	6.19	0.26	0.26	4.69	6.19
	0.4	0.26	0.27	5.40	7.05	0.28	0.28	5.40	7.05
$LSD_{0.05}$		**0.01**	**0.25**	**0.62**	**0.47**	**NS**	**NS**	**0.62**	**0.47**

$LSD_{0.05}$ is the least significant difference at 5% level of probability, NS is not significant.

Table 6-c. Average of oil percentage and oil yield per plant of *Ocimum basilicum* plants as affected by irrigation interval rates (IIR) and salicylic acid concentration (SAC) in the two cuttings at the two growing seasons

IIR (Day)	SAC (mM)	1st Season				2nd Season			
		Oil Percentage		Oil yield per plant		Oil Percentage		Oil yield per plant	
		1st Cut	2nd Cut	1st Cut	2nd Cut	1st Cut	2nd Cut	1st Cut	2nd Cut
4	Control	0.19	0.19	4.60	5.2	0.20	0.21	4.60	5.2
	0.1	0.21	0.22	5.25	5.99	0.22	0.23	5.25	5.99
	0.2	0.22	0.23	5.80	6.47	0.23	0.24	5.80	6.47
	0.4	0.22	0.24	6.17	6.89	0.25	0.26	6.17	6.89
7	Control	0.16	0.17	3.32	4.27	0.17	0.19	3.32	4.27
	0.1	0.18	0.19	3.88	4.85	0.19	0.19	3.88	4.85
	0.2	0.19	0.20	4.12	5.21	0.20	0.20	4.12	5.21
	0.4	0.19	0.2	4.29	5.53	0.21	0.21	4.29	5.53
$LSD_{0.05}$		**NS**	**0.04**	**0.32**	**0.19**	**NS**	**NS**	**0.32**	**0.19**

LSD0.05 is the least significant difference at 5% level of probability, NS is not significant.

Table 7. Average of oil percentage and oil yield of *Ocimum basilicum* plants as affected by the interaction between different water stress, irrigation intervals and salicylic acidin the twocuttings in the second growing seasons

Water × day × SA			1st Season				2nd Season			
			Oil percentage		Oil yield per plant		Oil percentage		Oil yield per plant	
Water	**Day**	**SA**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**	**1st Cut**	**2nd Cut**
100%	4	0.0	0.13	0.14	3.15	3.86	0.14	0.15	3.78	4.32
		0.1	.16	0.17	4.21	4.96	0.17	0.18	4.87	5.72
		0.2	0.16	0.17	4.05	4.89	0.18	0.19	5.19	5.83
		0.4	0.17	0.18	4.25	5.01	0.19	0.21	5.30	6.30
	7	0.0	0.12	0.13	2.41	2.99	0.13	0.14	2.97	3.43
		0.1	0.13	0.14	2.89	3.5	0.14	0.15	3.38	3.94
		0.2	0.13	0.15	2.73	3.6	0.15	0.15	3.50	3.87
		0.4	0.14	0.15	2.88	3.43	0.16	0.16	3.68	4.00
	4	0.0	0.2	0.2	4.41	4.91	0.22	0.23	5.76	6.36
75%		0.1	0.22	0.22	4.63	5.42	0.23	0.23	6.31	6.64
		0.2	0.23	0.23	5.44	5.87	0.24	0.25	6.76	7.38
		0.4	0.23	0.23	5.13	5.6	0.25	0.26	6.76	7.31
	7	0.0	0.18	0.19	3.24	3.82	0.19	0.20	3.99	4.43
		0.1	0.21	0.2	3.61	4.08	0.23	0.21	4.80	4.97
		0.2	0.22	0.21	4.29	4.42	0.22	0.23	4.91	5.56
		0.4	0.22	0.22	4.08	4.47	0.23	0.24	4.83	5.53
50%	4	0.0	0.24	0.25	3.6	4.03	0.25	0.26	4.25	4.94
		0.1	0.26	0.27	4.07	4.53	0.25	0.27	4.58	5.63
		0.2	0.27	0.28	4.41	4.89	0.28	0.29	5.44	6.19
		0.4	0.29	0.3	4.99	5.46	0.31	0.32	6.44	7.05
	7	0.0	0.19	0.2	2.47	2.82	0.20	0.22	3.00	4.94
		0.1	0.21	0.22	2.78	3.15	0.21	0.22	3.45	5.63
		0.2	0.22	0.23	2.98	3.32	0.23	0.23	3.94	6.19
		0.4	0.22	0.23	3.11	3.6	0.24	0.24	4.35	7.05
$LSD_{0.05}$			0.190	0.42	0.190	0.42	NS	NS	1.11	0.846

$LSD_{0.05}$ is the least significant difference at 5% level of probability, NS is not significant

The increase in oil output might be attributed to enhanced vegetative growth, nutrient intake, or changes in the population of leaf oil glands and monoterpenes. According to Tiwari & Banafar (1995) and Gharib (2006), increasing rates of N and P treatment improved total N and P absorption as well as essential oil output of *Coriandrum sativum* up to 60 and 45 kg per ha, respectively.

The interaction of the three studied factors (Table 7) revealed that significant means in oil yield in (2nd) cut during the 2nd seasons were observed primarily when plants were grown under (70%) soil moisture level and irrigation intervals (4 days) and sprayed with 0.4 mM (followed by 0.2 at the same level) salicylic acid only during the vegetative stage. These findings matched those of Al-Shukry & Abbas (2016) and Metwally *et al.* (2018).

CONCLUSION

Sweet basil (*Qcimum basilicum* L.) plants needs more water and sensitive to drought stress. Water stress treatments increased essential oil percentage. SA application in low concentration could effectively improve the growth of *Ocimum basilicum* plants under water stress.

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الملخص العربي

تأثيرالاجهاد المائي وحامض السالسيليك على النمو ومحصول الزيت فى نبات الريحان فى الأرض حديثة الاستصلاح

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أجرى هذا البحث خلال موسمين متتالين ٢٠١٧–٢٠١٨ في قرية الزهور– منطقة بنجر السكر التابعة لبرج العرب – محافظة الإسكندرية بهدف دراسة تأثيرالمحتوى المائي للتربة (مستويات مختلفة من السعة الحقلية) وكذلك التركيزات المختلفة من حامض السالسيليك على النموالخضرى وإنتاج الزيت فى نبات الريحان (*Ocimum basilicum* L.)، وقد استخدمت ٣ مستويات من الرى للحفاظ على المحتوى المائى للتربة عند نسبة ١٠٠%، ٧٥% و٥٠% من السعة الحقلية خلال موسم النمو وتم رى النباتات كل ٤ أيام أو كل ٧ أيام مع الرش بأربعة تركيزات من حامض السالسيليك هي ٠,٠ ، ٠,١ ، ٠,٢، ٠,٤ مللي مول. أظهرت النتائج أن الرش بتركيزات منخفضة (٠,١ – ٠,٤ مللى مول) من حامض السالسيليك أدى إلى تحسن فى النمو الخضرى وفي محتوى الزيت للأوراق وذلك تحت ظروف الاجهاد المائي وسجلت أعلى محتوى من نسبة الزيت عند مستوى ٥٠% من السعة الحقلية مع الرش بتركيز ٠,٤ مللي مول من حامض السالسيليك وتحت ظروف الإجهاد المعتدل اي مع فترة الري كل أربعة أيام.