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EFFECT OF SOME IRRIGATION LEVELS AND FOLIAR-SPRAY APPLICATION WITH SOME CHEMICAL SUBSTANCES ON GROWTH AND YIELD OF *SALVIA HISPANICA* IN EGYPT

[72]

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ABSTRACT

This study was carried out in two successive seasons (2014-2015 and 2015-2016) at SEKEM company Farm (Bilbase, Sharkya Governorate) on chia (*Salvia hispanica*) plant which is a new crop introduced lately to Egyptian cultivation as a medicinal plant. The effect of three irrigation levels of different reference evapotranspiration (80, 100 and 120 % ETo) with foliar application of three levels of proline (100, 200 and 300 ppm), salicylic acid (200, 400 and 600 ppm) and putrescine (10, 15 and 20 ppm) in addition to the control treatment (tap water) was investigated on growth and yield of *Salvia hispanica* cultivated in sandy loam soil with drip irrigation system. The results of the two years experiments indicated that the highest values of plant growth parameters and seeds yield of *S. hispanica* were obtained from 100 % ETo. While 120 % ETo resulted in the maximum value of roots fresh and dry weights. Foliar-spray application of proline (100 ppm.), salicylic acid (200 ppm) and putrescine (10 ppm) resulted in optimum fresh and dry weights of herbage and roots. Seed yield was higher in plants sprayed with proline (100 ppm) and putrescine (10 ppm), although the differences between them and salicylic acid (200 and 400 ppm) or putrescine (15 ppm) were insignificant in both seasons. This leads us to recommend irrigation of *S. hispanica* accordingly with 100 % ETo coupled with foliar-spray application of salicylic acid (200 ppm) from the economic point of view.

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INTRODUCTION

Salvia hispanica L. (Chia) is an annual herbaceous plant belonging to the mint family (*Lamiaceae*) and is native to southern Mexico and northern Guatemala **(Yeboah et al 2014 and Silva et al 2016).** It is currently commercially cultivated for its seeds in Australia, Bolivia, Colombia, Guatemala, Mexico, Peru, Ecuador and Argentina **(Jamboonsri et al 2012)**. This ancestral seed has been known for its medicinal and nutritional properties from ancient time because of its high content of omega-3 fatty acids, since it is one of the largest botanical sources of linoleic acid and it can easily be added to commercial products **(Coorey et al 2012)**. Chia plant was traditionally one of the four basic elements in the diet of Central American civilizations in the pre-Columbian epoch **(Baginsky et al 2016)**. Chia seeds offers a great future perspective for feed, food, medical, pharmaceutical and neutraceutical sectors, as they are a promising source of antioxidants which are believed to have cardiac, hepatic protective effects, anti-ageing and anti-carcinogenic characteristics and protect against cardiovascular diseases **(Ullah et al 2016).** It is widely consumed for various health benefits especially in maintaining healthy serum lipid level **(Ali et al 2012)**. Therapeutic effects of chia are scientifically established in the control of diabetes, dyslipidaemia, hypertension, as anti-inflammatory, anti-blood clotting, laxative, antidepressant, anti-anxiety, analgesic, vision and immune improver **(Ullah et al 2016)**.

Water is one of the most important inputs essential for crop production **(Al-Harbi et al 2008)**. Water deficit affects seriously the different aspects of plant biological processes such as growth, physiology, biochemistry and crop productivity. The increase of water demand in the world, especially in arid and semi-arid regions lead to farms searching for effective ways to use of water resources rationally **(Mansour et al 2014)**. Predicted climatic changes suggest that in the future it may be necessary to select species with low water requirements **(Herman et al 2016)** that efficiently produce large amounts of biomass, a desirable quality in species resistant to water stress **(De Almeida et al 2012 and Medrano et al 2015)**. *Salvia hispanica* L. (chia) is an interesting option, which has been described as being drought resistant while maintaining high growth under reduced water availability **(Herman et al 2016)**.

Irrigation scheduling is a process of determining when to irrigate and how much water to apply per irrigation **(Khan et al 2007)**. The impact of the climate on crop water supplies is given by the reference evapotranspiration (ETo) **(Doorenbos and Pruitt, 1977)**. Evapotranspiration (ET) is a process that describes the water a plant loses through evaporation and transpiration and shows direct correlation with various crops' production **(Ko and Piccinni, 2009; Romero and Dukes, 2010)**. In drought-related experiments, it is common to use ET-based irrigation treatments **(Devitt et al 1994; Costello et al 2000 and Beeson, 2006).** ET, along with potential evapotranspiration (ETo), are used to determine irrigation rates. Potential evapotranspiration (ETo) is an estimate of ET calculated using the Penman-Montieth equation and climatic data such as temperature, dew point, wind speed, and solar radiation **(Romero and Dukes, 2010).**

There are several commercially available chemical compounds that could be used as elicitors to modify plant secondary metabolites and subsequently the bioactivity of medicinal plants **(Pirbalouti et al 2014)**. Therefore, this work aimed to study the effect of three irrigation levels of reference evapotranspiration (80, 100 and 120 % ETo) with 10 foliar application treatments that included three levels of proline (100, 200 and 300 ppm), salicylic acid (200, 400 and 600 ppm) and putrescine (10, 15 and 20 ppm) in addition to a control treatment (tap water) on growth and yield of *Salvia hispanica* cultivated in sandy loam soil supplied with a drip irrigation system.

MATERIALS AND METHODS

Two years experiments were carried out at SEKEM company Farm (Bilbase, Sharkya Governorate) during 2014-2015 and 2015-2016 seasons. The soil of these experiments was sandy loam soil and Nile water was used under a drip irrigation system.

The physical and chemical characteristics of an experimental soil sample were determined each season before cultivation according to **Jackson (1973)** and are presented in **Table (1)**.

Table 1. Physical and chemical properties of the experimental soil during 2014-2015 and 2015-2016 seasons

Physical properties				
	Sand	Silt	Clay	Texture
2014-2015	76.8	8.0	15.2	Sandy loam
2015-2016	74.5	10.1	15.4	Sandy loam

Chemical properties										
pH		E.C. (dSm^{-1})	(meq/l)							
			Cations				Anions			
(1:2.5)		(1:5)	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO3^{-2}$	$HCO3^{-}$	Cl^{-}	SO4-2
2014-2015	7.47	0.8	2.5	0.5	2.84	0.4	-	1.4	2.96	1.95
2015-2016	7.78	0.5	2.0	0.5	3.94	0.4	-	1.9	3.33	2.44

Maximum, minimum, average air temperatures (^{o}C), relative humidity (R.H.) and refrence Evaporattion transpiration (ETo) of the experimental Farm area during the growing period of the two seasons are shown in **Table (2).**

Table 2. Monthly average of metrological data of the experimental Farm of ***SEKEM***, Bilbase during 2014-2015and 2015-2016 seasons

Metrological data					
	Air temperature (^{o}C)			R.H. (%)	ETo (mm/day)
Month	**Max.**	**Min.**	**Average**		
Oct. 2014	26.9	17.9	22.4	69.0	3.69
Nov. 2014	22.7	14.5	18.6	72.3	2.57
Dec. 2014	20.4	10.8	15.6	69.3	2.06
Jan. 2015	17.8	8.2	13.0	64.8	2.36
Oct. 2015	27.6	17.7	22.7	53.2	7.55
Nov. 2015	25.6	17.0	21.3	52.7	6.31
Dec. 2015	18.9	10.8	14.9	53.3	3.88
Jan. 2016	17.2	9.1	13.2	55.8	3.66

The layout of the experiments was a split-plot design incorporating 30 treatments. Each experiment contained the combinations between three irrigation levels (80, 100 and 120 % ETo) in the main plots with 10 foliar application treatments which included three levels of proline (100, 200 and 300 ppm), salicylic acid (200, 400 and 600 ppm) and putrescine (10, 15 and 20 ppm) in addition to the control treatment (tap water) in the subplots.

The soil was prepared before cultivation and divided into plots (2.1 m^2, 1 × 2.1 m) on 15th September for both seasons (2014-2015 and 2015-2016). During soil preparation 12 m^3 compost, 350 Kg calcium super phosphate and 75 Kg sulphur were added per feddan. All treatments were fertilized with ammonium nitrate (33.5 % N) at the rate of 200 Kg / Fed. which was divided into two portions; 60 Kg and 140 Kg after 35 and 63 days from sowing, in respect order.

The seeds of chia (*Salvia hispanica*) were imported from Original Hanoju Deutschland UG company, Germany and cultivated directly in hills at distance of 30 cm between each two hills and adjusted to dripper lines, which were 100 cm apart, on 1st October in both seasons (2014-2015 and 2015-2016). Plants were thinned to 4 plants / dripper (2 plants on each side of the dripper). The agricultural practices normally done for the other *Slavia* species were applied for cultivated *Salvia hispanica* plants. Plants were watered with a drip irrigation system (4 L/ hour) according to ETo which was used to calculate the time of irrigation of each treatment.

Proline, salicylic acid and putrescine with their different levels were applied two times during the two growing seasons at the age of 35 days and 63 days from sowing date.

Parameters of plant height (cm), number of branches / plant, fresh and dry weights of herbage (g/plant), fresh and dry weights of roots (g/plant) and seeds weight (g/plant) were all recorded in both seasons.

The result data recorded were analyzed by Duncan's multiple-range test **(Duncan, 1955)** using the General Linear Models procedure of CoStat **(Snedecor and Cochran, 1967)**.

RESULTS AND DISCUSSION

Plant height

Plant height responded significantly to irrigation levels (ETo), application of proline, salicylic acid and putrescine as well as to their interactions in both seasons (**Table, 3**).

The differences in plant height between 80% ETo, 100% ETo and 120% ETo were significant in the first season, while in the second season there were significant differences between 80 % ETo and the other two levels only. The highest plants were resulted from irrigation at 100 % ETo in both seasons.

The differences between the foliar application of proline (300 ppm), salicylic acid (600 ppm) and putrescine (20 ppm) were insignificant comparing with the control (tap water) in both seasons. Irrigation with 100 % Eto interacted with foliar application of salicylic acid (200 ppm) gave the highest values (118.4 and 125.0 cm in the 1st and 2nd seasons, respectively).

Table 3. Effect of irrigation levels and foliar-spray application of proline, salicylic acid or putrescine on plant height (cm) and number of branches / plant of *Salvia hispanica* during 2014-2015 and 2015-2016 seasons

Foliar-Spray Application	First Season (2014-2015)				Second Season (2015-2016)			
	Irrigation Levels			Mean	Irrigation Levels			Mean
	80 % ETo	100 % ETo	120 % ETo		80 % ETo	100 % ETo	120 % ETo	
Plant height								
Control (Tap water)	93.8 i	110.0 b-e	103.7 e-h	102.5 E	95.1 g	113.1 b-d	114.3 a-c	107.5 D
Proline 100 ppm	105.0 d-g	117.0 ab	116.7ab	112.9 A	101.2 fg	118.7 a-c	118.0 a-c	112.6 B-D
Proline 200 ppm	106.2 d-g	112.3 a-d	110.2 b-e	109.6 A-C	102.4 e-g	120.3 ab	117.7 a-c	113.5 BC
Proline 300 ppm	101.0 f-h	109.3 a-e	107.9 c-f	106.1 CD	99.4 fg	117.3 a-c	116.0 a-c	110.9 CD
Salicylic acid 200 ppm	104.3 d-h	118.4 a	114.0 a-d	112.2 A	112.7 b-d	125.0 a	118.1 a-c	118.6 A
Salicylic acid 400 ppm	100.4 f-i	115.1 a-c	112.1 a-d	109.2 A-C	116.0 a-c	114.8 bc	115.9 a-c	115.6 AB
Salicylic acid 600 ppm	98.6 g-i	111.0 a-e	105.2 d-g	104.9 DE	105.9 d-f	116.0 a-c	109.0 c-e	110.3 CD
Putrescine 10 ppm	98.6 g-i	114.5 a-c	109.2 b-e	107.4 B-D	99.7 fg	118.0 a-c	115.0 bc	110.9 CD
Putrescine 15 ppm	99.3 g-i	115.8 a-c	115.2 a-c	110.1 AB	99.6 fg	114.3bc	118.3 a-c	110.7 CD
Putrescine 20 ppm	97.0 fhi	109.6 b-e	105.7 d-g	104.1 DE	102.3 e-g	113.1 bc	115.6 a-c	110.3 CD
Mean	**100.4 *C***	**113.3 *A***	**110.0 *B***		**103.4 *B***	**117.1 *A***	**115.8 *A***	
Number of branches / plant								
Control (Tap water)	14.7 ab	14.3 ab	13.3 ab	14.1 AB	13.0 ab	16.0 a	14.0 ab	14.3 A
Proline 100 ppm	15.3 a	15.0 a	13.3 ab	14.6 A	14.3 ab	13.7 ab	14.0 ab	14.0 A
Proline 200 ppm	14.0 ab	14.3 ab	13.3 ab	13.9 AB	13.7 ab	13.7 ab	14.3 ab	13.9 A
Proline 300 ppm	12.3 ab	13.0 ab	13.0 ab	12.8 AB	13.0 ab	14.3 ab	13.3 ab	13.6 A
Salicylic acid 200 ppm	11.7 b	13.3 ab	13.0 ab	12.7 B	14.7 ab	14.3 ab	13.0 ab	14.0 A
Salicylic acid 400 ppm	13.0 ab	12.7 ab	13.7 ab	13.1 AB	13.7 ab	13.7 ab	14.3 ab	13.9 A
Salicylic acid 600 ppm	13.0 ab	13.3 ab	15.0 a	13.8 AB	11.7 b	13.7 ab	14.3 ab	13.2 A
Putrescine 10 ppm	15.0 a	13.0 ab	12.3 ab	13.4 AB	13.7 ab	13.0 ab	14.3 ab	13.7 A
Putrescine 15 ppm	11.0 ab	14.0 ab	13.7 ab	12.9 AB	14.0 ab	14.0 ab	14.3 ab	14.1 A
Putrescine 20 ppm	14.0 ab	14.0 ab	12.7 ab	13.6 AB	13.3 ab	13.7 ab	15.0 ab	14.0 A
Mean	**13.4 *A***	**13.7 *A***	**13.3 *A***		**13.5 *A***	**14.0 *A***	**14.1 *A***	

*Means with the same letters are not significantly different at the 5 % probability level

*Means with the different letters are significantly different at the 5 % probability level

Application of proline, salicylic acid and putrescine in the minimum concentration increased significantly means of plant height in the 1st season.

Number of branches / plant

Results showed that neither irrigation levels (ETo), foliar application nor their interactions affected significantly the number of branches / plant in both seasons **(Table, 3).**

Herb fresh and dry weights (g / plant)

Clearly, irrigation levels in addition to the different levels of foliar application treatments as well as their interactions affected significantly herb fresh dry weights of chia plant in both seasons **(Table, 4)**.

Irrigation at 80 and 120 % ETo produced the lowest fresh and dry weights, respectively in both seasons. On the other hand, the most effective irrigation level for production of *Salvia hispanica* fresh and dry weights was at 100 % Eto which gave the greatest values (141.5 and 169.8 g fresh weight / plant; 51.7 and 67.5 g dry weight / plant in the 1st and 2nd seasons, respectively).

Table 4. Effect of irrigation levels and foliar-spray application of proline, salicylic acid or putrescine on herb fresh and dry weights (g / plant) of *Salvia hispanica* during 2014-2015 and 2015-2016 seasons

Foliar-Spray Application	First Season (2014-2015)				Second Season (2015-2016)			
	Irrigation Levels			Mean	Irrigation Levels			Mean
	80 % ETo	100 % ETo	120 % ETo		80 % ETo	100 % ETo	120 % ETo	
Herb fresh weight								
Control (Tap water)	108.3 g-j	121.5 d-i	141.3 b-f	123.7 C	125.9 f-i	134.2 e-i	163.8 c-h	141.3 C
Proline 100 ppm	134.2 c-g	168.7 ab	113.6 f-j	138.9 B	161.5 c-h	222.1 a	148.9 c-i	177.5 A
Proline 200 ppm	90.5 j	115.8 e-j	110.0g-j	105.4 D	107.2 i	164.9 c-h	133.1 f-i	135.1 C
Proline 300 ppm	102.0 h-j	100.4 ij	108.4 g-j	103.6 D	119.5 hi	110.5 i	125.6 f-i	118.6 D
Salicylic acid 200 ppm	118.5 d-j	154.2 a-c	152.5 a-c	141.7 B	138.5 d-i	190.5 bc	178.8 b-e	169.3 AB
Salicylic acid 400 ppm	119.5 d-j	125.3 c-i	113.4 f-j	119.4 C	140.1 d-i	150.4 c-i	128.1 f-i	139.5 C
Salicylic acid 600 ppm	106.3 g-j	153.0 a-c	128.9 c-i	129.4 BC	123.8 g-i	183.2 b-d	147.1 c-i	151.4 BC
Putrescine 10 ppm	146.9 b-d	176.9 a	148.0 b-d	157.3 A	169.5 c-g	211.2 ab	169.2 c-g	183.3 A
Putrescine 15 ppm	129.3 c-i	154.5 a-c	132.1 c-h	138.6 B	144.0 d-i	171.8 c-f	147.6 c-i	154.5 BC
Putrescine 20 ppm	126.9 c-i	144.8 b-e	143.5 b-e	138.4 B	136.4 d-i	159.0 c-h	158.1 c-h	151.2 BC
Mean	**118.2 *C***	**141.5 *A***	**129.2 *B***		**136.6 *C***	**169.8 *A***	**150.0 *B***	
Herb dry weight								
Control (Tap water)	41.7 e-i	42.3 e-i	45.1 d-h	43.0 D	52.4 e-h	50.5 e-h	56.6 d-h	53.2 C
Proline 100 ppm	40.3 f-i	62.9 ab	36.2 g-i	46.5 CD	52.6 e-h	89.9 a	51.5 e-h	64.7 B
Proline 200 ppm	33.4 hi	50.6 c-f	31.2 i	38.4 E	42.5 gh	78.1 a-c	40.7 h	53.8 C
Proline 300 ppm	43.3 e-i	33.7 hi	33.4 hi	36.8 E	54.8 e-h	40.5 h	41.8 h	45.7 D
Salicylic acid 200 ppm	40.7 f-i	53.3 b-f	47.8 d-g	47.3 CD	51.3 e-h	71.3 b-e	60.4 c-g	61.0 BC
Salicylic acid 400 ppm	48.5 d-g	42.0 e-i	42.7 e-i	44.4 D	61.4 c-g	54.7 e-h	51.3 e-h	55.8 BC
Salicylic acid 600 ppm	45.1 d-h	54.3 b-e	40.4 f-i	46.6 CD	56.7 d-h	70.3 b-f	49.7 f-h	58.9 BC
Putrescine 10 ppm	68.1 a	67.9 a	61.6 a-c	65.9 A	77.2 a-c	87.7 a	76.2 a-d	80.3 A
Putrescine 15 ppm	52.4 b-f	56.9 b-d	53.2 b-f	54.1 B	63.1 c-g	68.5 b-f	64.1 c-f	65.2 B
Putrescine 20 ppm	46.7 d-g	53.2 b-f	52.9 b-f	51.0 BC	56.4 d-h	63.2 c-g	63.0 c-g	60.9 BC
Mean	**46.0 *B***	**51.7 *A***	**44.4 *B***		**56.9 *B***	**67.5 *A***	**55.5 *B***	

* Means with the same letters are not significantly different at the 5 % probability level
*Means with the different letters are significantly different at the 5 % probability level

Application of 10 ppm putrescine as a foliar spray was superior in promoting herb fresh and dry weights / plant comparing to other treatments which gave 157.3 and 183.3 g fresh weight / plant; 65.9 and 80.3 g dry weight / plant in 1st and 2nd seasons, respectively, while their minimum values (103.6 and 118.6 g fresh weight / plant; 36.8 and 45.7 g dry weight / plant in 1st and 2nd seasons, respectively) were observed from proline in the 300 ppm treatment.

The maximum fresh and dry weights resulted from plants irrigated with 100 % ETo and foliar sprayed with 10 ppm putrescine (167.9 g fresh weight / plant and 67.9 g dry weight / plant in the 1st season) and with 100 % ETo and proline 100 ppm (222.1 g fresh weight / plant and 89.9 g dry weight / plant in the 2nd season).

Root fresh and dry weights (g / plant)

Data in **Table (5)** showed significant effects of irrigation rate (ETo), in addition to foliar applications and their interactions on root fresh and dry weights in the 1st and 2nd seasnos, except the foliar application effect on root fresh weight in the second season that was insignificant.

Increasing irrigation levels significantly increased root fresh and dry weights in both seasons. The most effective irrigation rate was 120% ETo, which gave the highest mean values (20.8 and 26.2 g for root fresh weight; 6.7 and 8.1 g for root dry weight in the 1st and 2nd seasons, respectively). While irrigation at 80% ETo resulted in the lowest mean values (14.4 and 17.8 g for root fresh weight; 4.5 and 5.8 g for root dry weight in the 1st and 2nd seasons, respectively).

Table 5. Effect of irrigation levels and foliar-spray application of proline, salicylic acid or putrescine on root fresh and dry weights / plant of *Salvia hispanica* during 2014-2015 and 2015-2016 seasons

Foliar-Spray Application	First Season (2014-2015)				Second Season (2015-2016)			
	Irrigation Levels			Mean	Irrigation Levels			Mean
	80 % ETo	100 % ETo	120 % ETo		80 % ETo	100 % ETo	120 % ETo	
Root fresh weight (g)								
Control (Tap water)	12.6 fg	16.3 c-g	19.8 a-f	16.2 B	15.9 bc	21.0 a-c	24.3 a-c	20.4 A
Proline 100 ppm	16.3 c-g	21.6 a-d	25.2 a	21.0 A	20.1 a-c	25.0 a-c	32.2 a	25.8 A
Proline 200 ppm	15.2 c-g	17.3 c-g	20.8 a-e	17.7 B	18.5 a-c	24.8 a-c	27.3 a-c	23.5 A
Proline 300 ppm	14.1 d-g	16.8 c-g	18.6 a-g	16.5 B	15.3 c	23.3 a-c	24.7 a-c	21.1 A
Salicylic acid 200 ppm	16.4 c-g	22.2 a-c	24.6 ab	21.0 A	20.2 a-c	25.7 a-c	28.2 a-c	24.7 A
Salicylic acid 400 ppm	13.7 e-g	17.1 c-g	19.4 a-g	16.7 B	16.1 bc	21.0 a-c	24.3 a-c	20.5 A
Salicylic acid 600 ppm	12.0 g	15.5 c-g	17.4 c-g	15.0 B	16.0 bc	19.8 a-c	20.8 a-c	18.8 A
Putrescine 10 ppm	15.9 c-g	21.9 a-c	25.0 a	20.9 A	20.4 a-c	24.5 a-c	30.2 b	25.0 A
Putrescine 15 ppm	15.0 c-g	17.9 b-g	19.5 a-g	17.5 B	19.2 a-c	21.6 a-c	27.4 a-c	22.7 A
Putrescine 20 ppm	13.2 e-g	16.5 c-g	17.3 c-g	15.6 B	16.3 bc	18.6 a-c	22.4 a-c	19.1 A
Mean	**14.4 *C***	**18.3 *B***	**20.8 *A***		**17.8 *C***	**22.5 *B***	**26.2 *A***	
Root dry weight (g)								
Control (Tap water)	4.0 de	5.3 a-e	6.4 a-e	5.2 B	5.1 b	6.9 ab	7.8 ab	6.6 AB
Proline 100 ppm	5.0 b-e	6.9 a-d	8.1 a	6.6 A	6.5 ab	7.5 ab	10.6 a	8.2 A
Proline 200 ppm	4.6 b-e	5.2 b-e	6.9 a-d	5.6 AB	5.9 b	8.1 ab	8.0 ab	7.3 AB
Proline 300 ppm	4.4 c-e	5.2 a-e	6.3 a-e	5.3 B	4.7 b	7.7 ab	7.9 ab	6.8 AB
Salicylic acid 200 ppm	5.1 a-e	7.1 a-c	7.4 ab	6.6 A	6.0 b	8.2 ab	8.4 ab	7.6 AB
Salicylic acid 400 ppm	4.3 c-e	5.2 a-e	6.3 a-e	5.3 B	5.9 b	6.0 b	7.6 ab	6.5 AB
Salicylic acid 600 ppm	3.7 e	4.7 b-e	5.4 a-e	4.6 B	5.2 b	6.4 ab	6.2 ab	5.9 B
Putrescine 10 ppm	5.3 a-e	7.0 a-d	8.1 a	6.8 A	7.0 ab	7.3 ab	9.0 ab	7.8 AB
Putrescine 15 ppm	4.9 b-e	5.8 a-e	6.2 a-e	5.6 AB	6.2 ab	7.0 ab	8.3 ab	7.2 AB
Putrescine 20 ppm	4.1 c-e	5.4 a-e	5.7 a-e	5.1 B	5.4 b	5.9 b	7.4 ab	6.2 AB
Mean	**4.5 *C***	**5.8 *B***	**6.7 *A***		**5.8 *C***	**7.1 *B***	**8.1 *A***	

*Means with the same letters are not significantly different at the 5 % probability level
*Means with the different letters are significantly different at the 5 % probability level

Foliar spraying chia plants with 100 ppm proline, 200 ppm salicylic acid and 10 ppm putrescine resulted in the maximum root fresh and dry weights in the 1st season, while spraying chia plants with 100 ppm proline resulted in the maximum root dry weight in the 2nd season.

Irrigation at 120 % ETo when interacted with proline 100 ppm treatment showed the highest fresh and dry weights of roots (25.2 and 32.2 g root fresh weight; 8.1 and 10.6 g root dry weight in 1st and 2nd seasons, respectively).

Seeds weight (g/plant) and seeds yield (Kg/feddan)

Chia seeds weight (g/plant) and yield (kg/feddan) responded significantly to the different applied treatments which was quite obvious in both seasons **(Table, 6)**.

The maximum seeds weight (17.7 and 18.9 g / plant in both seasons, respectively) and maximum seeds yield (943.50 and 1006.29 Kg / feddan in the first and second seasons, respectively) resulted from plants irrigated at 100 % ETo. Irrigation level at 80 % Eto showed the lowest values when compared to the other two levels for seeds weight and yield in both seasons, although there was insignificant difference between 80 % and 120 % ETo in the first season.

Putrescine foliar sprayed at 10 ppm in the first season gave the extremely high values of seeds weight and yield (18.0 g and 959.8 Kg, respectively), whereas the highest ever mean value (20.1 g and 1070.9 Kg, respectively) resulted from application of 100 ppm proline in the second season.

Evidently, irrigation at 100% ETo when interacted with putrescine 10 ppm led to the greatest seeds weight and yield (20.9 and 22.0 g; 1115.9 and 1171.4 Kg in 1^{st} and 2^{nd} season, respectively).

Our results related to the effect of irrigation treatments are in accordance with those of **Singh-Sangwan et al (2001)** on *Plumbago zeylanica*, **Tantawy et al (2007)** on sesame **Ahmed and Mahmoud (2010**) on *Sesamum indicum*, **Kharadi et al (2011**) on *Plumbago zeylanica*, **Corell et al (2012)** on *Salvia officinalis*, **Khalil and El-Noemani (2012)** on *Lepidium sativum* and **Herman et al (2016)** on *Salvia hispanica*.

Elsewhere, it was found that increasing irrigation level up to 100% Eto raised vegetative growth, i.e. plant height, branches number as well as dry matter of stem and hole plant **(El-Noemani et al 2009**). The strong influence of increasing irrigation up to the maximum level on plant height could be explained by enhancing cell division and enlargement which need more water supplies **(Hammad, 1991)**. **Fatthallah and Gawish (1997)** pointed out that the reduction in number of branches owing to the low soil moisture level may be due to the reduction in the uptake of nutritional elements that caused inhibition in the physiological processes needed for plant growth. The increase in dry matter of plants grown in high levels of soil moisture could be attributed mainly to the effect of water on some quantitative and qualitative changes in certain metabolic processes in the plant cell **(Mahmoud, 2000)**. On the contrary, shortening plant height and lower dry matter under soil moisture stress may be explained by the fact that water stress caused stomatal closure and reduced minerals uptake by plants and hence affected plant growth **(El-Noemani et al 2010**).

The decline in fresh weight could be attributed to the decrease in water content of stressed plant cells and tissues which lose their turgor and thus shrink **(Boyer, 1982)** and the reduction of applied water may affect the physiological processes and tends to expose the plants to water stress which will be reflected to the water absorption and transmission to the different parts of the plant **(Al-Harbi et al 2008**). The decrease in both fresh and dry weights of stressed plants is tied up by the influence of water on stimulating and regulating the photosynthetic enzymes **(Abdalla and El Khoshiban, 2007)**. Water-deficit conditions significantly reduces considerably characteristics of transpiration rate and photosynthetic capacity of plants by stomatal closure or through metabolic impairments such as damaging proteins associated with chlorophyll **(Lawlor and Cornic, 2002; Athar and Ashraf, 2005)**. This may probably interpret a strategy of assimilate distribution, for example in stomatal control of water loss and in osmotic adjustment. Thus chia is sensitive to the lack of water, but adopts adaptive strategies that maintains its yield (**Herman et al 2016)**.

The shoot dry weight percentage here in chia decreased with increasing irrigation rate. It could be attributed to the reduction of applied water which, as explained earlier, may affect the physiological processes and tended to expose the plants to water stress which will be reflected to the water absorption and transmission to the different parts of the plant **(Al-Harbi et al 2008)**.

The decrease in yield attributes of chia may be due to that water stress caused a change in the hormonal balance of mature leaves, thus enhancing leaf senescence and hence the number of active leaves decreased. In addition, leaf area was reduced by water shortage, which was attributed to its effect on cell division and lamina expansion, when the leaf level decreased the light attraction and CO_2 diffusion inside the leaf decreased and the total capacity of photosynthesis decreased therefore the photosynthetic materials that are transferred to seeds will eventually decrease **(Ahmed and Mahmoud, 2010; Moussavi et al 2011)**.

Obtained results here regarding proline application are similar to those obtained by **Abd El-hamid et al (2016)** on fenugreek, **El-Sherbeny and DA Silva (2013)** on beetroot**, Gamal El-Din and Abd El-Wahed (2005)** on *Matricaria chamomilla* L. Rausch**, Ali et al (2007)** on maize**, Khalil and El-Noemani (2012)** on *Lepidium sativum*, **Qayyum et al (2007)** on wheat and **Deivanai et al (2011)** on rice.

The increases in growth characters caused by application of different proline concentrations might be due to the role of proline in protecting enzymes, 3D structures of proteins and organelle membranes and also it supplies energy for growth and survival thereby helping the plant to tolerate stress

Table 6. Effect of irrigation levels and foliar-spray application of proline, salicylic acid or putrescine on seeds weight / plant and yield / Feddan of *Salvia hispanica* during 2014-2015 and 2015-2016 seasons

Foliar-Spray Application	First Season (2014-2015)				Second Season (2015-2016)			
	Irrigation Levels			Mean	Irrigation Levels			Mean
	80 % ETo	100 % ETo	120 % ETo		80 % ETo	100 % ETo	120 % ETo	
Seeds weight (g/plant)								
Control (Tap water)	11.6 a-c	15.9 a-c	13.2 a-c	13.6 BC	13.1 c	16.1 a-c	14.9 bc	14.7 E
Proline 100 ppm	14.9 a-c	20.7 ab	16.7 a-c	17.4 AB	19.0 a-c	21.2 ab	20.1 a-c	20.1 A
Proline 200 ppm	12.8 a-c	17.0 a-c	14.5 a-c	14.8 A-C	16.4 a-c	19.8 a-c	18.3 a-c	18.2 A-D
Proline 300 ppm	11.0 c	15.2 a-c	11.6 a-c	12.6 C	14.1 c	16.5 a-c	15.0 bc	15.2 DE
Salicylic acid 200 ppm	14.0 a-c	18.1 a-c	16.7 a-c	16.3 A-C	17.1 a-c	19.7 a-c	19.2 a-c	18.7 A-C
Salicylic acid 400 ppm	13.6 a-c	16.1 a-c	15.1 a-c	14.9 A-C	15.2 bc	18.7 a-c	17.5 a-c	17.1 B-E
Salicylic acid 600 ppm	12.6 a-c	15.5 a-c	11.3 bc	13.1 BC	14.0 c	17.5 a-c	14.0 c	15.1 DE
Putrescine 10 ppm	15.9 a-c	20.9 a	17.2 a-c	18.0 A	17.4 a-c	22.0 a	20.0 a-c	19.8 AB
Putrescine 15 ppm	13.2 a-c	19.3 a-c	15.7	16.1 A-C	14.5 bc	18.9 a-c	16.5 a-c	16.6 B-E
Putrescine 20 ppm	11.2 bc	18.3 a-c	13.1 a-c	14.2 A-C	13.8 c	18.5 a-c	15.5 a-c	15.9 C-E
Mean	**13.1 *B***	**17.7 *A***	**14.5 *B***		**15.5 *C***	**18.9 *A***	**17.1 *B***	
Seeds Yield (Kg/Fed.)								
Control (Tap water)	620.6 a-c	848.3 a-c	702.6 a-c	723.9 BC	701.0 c	856.0 a-c	793.4 bc	783.5 E
Proline 100 ppm	795.3 a-c	1101.5 ab	890.3 a-c	929.1 AB	1012.3 a-c	1128.5 ab	1072.0 a-c	1070.9 A
Proline 200 ppm	682.4 a-c	907.4 a-c	772.1 a-c	787.3 A-C	874.1 a-c	1054.8 a-c	977.2 a-c	968.7 A-D
Proline 300 ppm	586.3 c	808.7 a-c	621.2 a-c	672.1 C	752.9 c	878.0 a-c	801.2 bc	810.7 DE
Salicylic acid 200 ppm	747.5 a-c	964.4 a-c	890.8 a-c	867.6 A-C	910.9 a-c	1051.4 a-c	1026.1 a-c	996.2 A-C
Salicylic acid 400 ppm	723.73 a-c	856.2 a-c	807.1 a-c	795.7 A-C	811.2 bc	994.8 a-c	932.1 a-c	912.7 B-E
Salicylic acid 600 ppm	670.7 a-c	825.2 a-c	604.8 a-c	700.3 BC	745.6 c	932.8 a-c	745.2 c	807.9 DE
Putrescine 10 ppm	845.5 a-c	1115.9 a	917.9 a-c	959.8 A	929.4 a-c	1171.4 a	1066.7 a-c	1055.8 AB
Putrescine 15 ppm	702.0 a-c	1029.7 a-c	836.3 a-c	856.0 A-C	773.3 bc	1010.5 a-c	877.9 a-c	887.2 B-E
Putrescine 20 ppm	596.1 bc	977.6 a-c	697.2 a-c	757.5 A-C	736.7 c	984.7 a-c	826.1 a-c	849.2 C-E
Mean	**697.05 *B***	**943.50 *A***	**774.03 *B***		**824.75 *C***	**1006.29 *A***	**911.80 *B***	

*Means with the same letters are not significantly different at the 5 % probability level
*Means with the different letters are significantly different at the 5 % probability level

(Hoque et al 2007 and Ashraf and Foolad, 2007). It is probable that proline would have been absorbed by the developing seedlings, where it maintained water status by increasing the influx of water and reducing the efflux of water under water-limiting conditions **(Chen and Murata, 2008)** and thus increased growth and yield **(Abd Elhamid et al 2016)**. Moreover, foliar application of proline enhanced growth of water stressed plants by enhancing photosynthetic capacity **(Ali et al 2007)** which support the arguments made by **Nátr and Lawlor (2005)** that different situations under different scenarios can be tried to enhance the final biological or economical yield by increasing the rate of photosynthesis.

On the other hand, the reduction in growth characters under the highest proline concentration may be attributed to that high concentrations of proline were harmful to plants, including inhibitory effects on growth or deleterious effects on cellular metabolisms **(Nanjo et al 2003 and Deivanai et al 2011)** and on root growth caused by greater accumulation of proline that may interfere with osmotic adjustment **(Amzallag, 2002)**.

Results here related to salicylic acid (SA) foliar application are similar to those obtained by **Haider and Saifullah (2001)** on potato**, Gharib (2006)** on sweet basil (*Ocimum basilicum*) and marjoram (*Majorana hortensis*)**, Noreen and Ashraf (2008)** on sunflower**, Kadioglu et al (2011)** on capsicum, **Afshari et al (2013)** on cowpea, **Farjam et al (2014)** on chickpea (*Cicer arietinum* L.) and **Zeid et al (2014)** on ajwain (*Trachyspermum ammi*).

The exogenous application of SA counteracts drought stress that hinders plant growth in different crop species, this role of SA may be attributed to its ability to improve photosynthetic parameters and plant water status. Increased transpiration rate and proline accumulation as a result of exogenous SA might also be effective mechanisms that protect the plant against the injuring effects of water deficit. In Confirmation, the application of SA improved all the measured traits and induced drought tolerance in the treated plants (**Afshari et al 2013)**.

SA adjusts the hormonal conditions of the plants and increases the levels of auxin and cytokinin in non-stress conditions **(Farjam et al 2014)**. The application of SA on plants increased the amounts of auxin and ABA and prevented the reduction of cytokinin in drought stress conditions **(Shakirova et al 2003).** Although drought stress hampered the plant water relations, the exogenous application of SA maintained the tissue water status possibly by stimulating the proton pumping **(Khripach et al 2003)**.

The response of chia plant to putrescine application is compatible with results obtained by **Sharma (1999)** on soybean and Pea, **Farooq and Wahid (2009)** on rice, **Gupta and Gupta (2009)** on wheat, **(Gupta et al 2012)** on wheat and **Zeid et al (2014)** on ajwain (*Trachyspermum ammi*).

Many previous studies improved that putrescine decreases the sensitivity of plants towards water stress, as polyamines can protect the different activities of the whole electron transport chain, photosystem I and Π. Increase in yield attributes of chia at stressed plants over the control plants could be because of the role of putrescine in stimulation of many processes inside the plant cell such as respiration and photosynthesis and increased the different photosynthetic products and the plants contents of protein and total amino acids under such drought stress level. Therefore, putrescine is found to be of bio-regulatory effects, chiefly through mobilization of dry matter and translocation of photosynthates resulting in an improved yield formation **(Ahmed and Sadak, 2016)**. In further details, putrescine can protect the membranes and other macro molecules from oxidative damages and thus can stabilize biological membranes under stressful conditions **(Gupta et al 2012)**.

Conclusion

Data showed that: Chia (*Salvia hispanica*) could be cultivated successfully in Egypt.

The highest yield of seeds was obtained from plants irrigated according to 100% ETo. Foliar application of proline (100 ppm) and putrescine (10 ppm) was superior to the other treatments, although there was no significant differences between them and salicylic acid (200 ppm) and putrescine (15 ppm).

From the previous data we can recommend irrigating chia (*Salvia hispanica*) plants according to 100 % ETo in combination with foliar-spray application of salicylic acid at 200 ppm for the highest yield from an economic point of view.

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