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Salicylic Acid Enhances Growth, Yield and Quality of Lettuce Plants (Lactuca sativa L.) under Drought Stress Conditions

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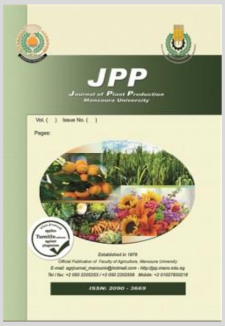

ABSTRACT

The current study was conducted to evaluate the effect of foliar application of salicylic acid treatments on growth, yield and quality of lettuce plants cv "Big Bell" that grown under water deficit stress. A field experiment was carried out during 2018-2019 and 2019-2020 seasons at the Experimental Farm, Faculty of Agriculture, Cairo University, Egypt. Drought was induced by withholding watering for 15 days after salicylic acid (SA) application exactly at 20 and 30 days after trasplanting. Five treatments were utilized. These were water-stressed +100 ppm of SA, water-stressed +200 ppm of SA, water-stressed +300 ppm of SA foliar spray, water-stressed only, and the fifth group served as control. Results indicated that water stress adversely affected growth and productivity parameters of lettuce cultivar "Big Bell". Water stressed plants at earlier stage of growth (20 day stage) were more inhibitory as compared with the plants at the age of 30. Generally, foliar spraying with salicylic acid significantly protected against the stress and increased root length, root weight, fresh head weight, head diameter, photosynthetic pigments compared to treatment that under water deficit. However, proline content increased under drought as well as under SA treatments. Spraying of salicylic acid at 200 ppm at the age of 30 was the most effective treatment that causing significant increase in yield by18.31% and 26.9% relative to control treatment in the first and second seasons, respectively. Application with salicylic acid increases drought tolerance and avoids the deleterious effect of water stress.

Keywords: Salicylic Acid, Drought Stress, Growth, Yield, Quality, Lettuce

INTRODUCTION

Climate change is considered as the most challenges of 21st century (Fita, 2015). Environmental stresses, such as drought, salinity, heat and low temperatures cause negative effects on plants growth and productivity of crops. Water is considered as one of the most important environmental factors that affect and regulate plant growth and development. Water scarcity will affect food security and economic activities. Globally, water resources will be enough to produce the food required in the next few years, but many regions will suffer from substantial water shortages. Water scarcity will result in increasing competition which will affect production and therefore incomes. Water deficit greatly reduces the growth of shoots (Nielson and Nelson, 1998). Thus, the aim of this investigation to overcome water stress, secure the efficient use of water and maximizing their use by increasing agricultural productivity and that is the key to improving food security.

In recent years, many studies have indicated that foliar application of salicylic acid leads to great effect on plant adaptation to stress factors including heat tolerance (Dat *et al*., 1998 a, b), salinity tolerance (Arfan *et al*. 2007and Stevens *et al*. 2006), chilling tolerance and drought tolerance (Singh and Usha, 2003;Yazdanpanah *et al*., 2011and Horva´th *et al*., 2007). Beside the additional role as it enhances growth, productivity and quality of many crops (Kawano *et al*., 2004) it is safe regarding to human health (Peng and Yueming, 2006). Salicylic acid is considered as endogenous growth regulator of phenolic nature (Hayat *et al*., 2010), that produced normally in plants in very small quantities (Raskin, 1992) and also regulates different physiological processes in plants such as plant growth, photosynthesis and enzyme activities (Hayat *et al*., 2010)

Lettuce is a vegetable that cultivated for fresh. Lettuce is one of the important world-wide dietary products which contains phenolic compounds and carotenoids such as lutein and E-carotene as well as of vitamin E (Nicolle *et al*. 2004). , lettuce leaves are considered as an important source of antioxidants, vitamins A and C (Norman, 1992) ،and anti-carcinogenic (Masarirambi *et al*., 2012)

The aim of this research work was to asses if the exogenous application of SA could ameliorate the adverse effect of drought stress on lettuce plants and also to determine the interactive impacts of water stress and salicylic acid on growth, yield and quality expressed by the contents of, chlorophyll, total sugar, ascorbic acid content (mg/100 g leaf fresh weight). Chlorophyll a, b and total and Carotenoids, Carbohydrates (mg/g), proline (μm/g FW) and total phenolic (mg/g) of 'lettuce plants cv. "Big bell" during water deficit stress.

MATERIALS AND METHODS

Description of the study site:

This study was carried out at the Experimental Farm of Faculty of Agriculture, Cairo University, in Giza Governorate, Egypt, during 2018- 2019and 2019-2020

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seasons. Lettuce transplants of Big bell cultivar lettuce plants were grown under water stress to evaluate the influence of salicylic acid at different levels on growth, yield and quality of lettuce plants comparing with treatment that under same conditions of water stress and not treated with SA and control treatment (supplying water at regular intervals).Lettuce transplants of 'Big bell cultivar' obtained from the Ministry of Agriculture Nurseries, Cairo, Egypt.

Experimental design and tested treatments: The experiment was conducted using three replications as randomized complete-block design. Each experimental plot consisted of two rows. Each row was 3.5 meters long and with 70 cm width. Planting distance were 20 cm apart. Seeds were sown on both sides of ridge. There were 60 plants in each plot .Each replicate consisted of nine treatments. Lettuce transplants were planted on10th and 7th of November in both growing seasons respectively. Drought treatments began at 20 days after transplants cultivation in the both seasons. Stress was imposed by withholding water. At the 20-day stage plants were divided into different sets. In the first set, water stress was applied for plants at the age of 20 by withholding water for 15 days. In the second set water stress was applied for that at the age of 30 by withholding water for 15 days and in the third set, plants was maintained by supplying water at regular intervals (control treatment). Plants were grouped into four groups in first and second previous sets, and the foliage had 0,100,200and300 ppm salicylic acid (SA) supplied. Salicylic acid (SA) was dissolved in absolute ethanol then added drop-wise to water (ethanol/water: 1/1000, v/v). The pH of all solutions was set to 6.5-7. All foliar sprayings were carried out early in the morning. Agricultural practices of irrigation, pest control…, etc., were applied as recommended for lettuce production (Hassan, 1991).

Data recorded:

Vegetative growth and yield characters:

Random samples of ten plants were taken from each plot to determine the head diameter (cm), head fresh weight (g), root weight (g), and root length (cm). Samples were dried in an oven at 70°C until constant weight to record the head dry weight (g). Plants of each plot were weight and expressed as total yield/fed.

Chemical constituents of leaves:

Chlorophyll a (Chl a) and b (Chl b) were extracted with 100 % ethanol several times until the extract became colorless. Their levels were calculated as previously described by López-Orenes *et al*. (2013). Ethanol extracts of fresh materials were used for the determination of total sugars, and total soluble phenols. Total sugar was determined by using the phenol-sulphuric acid method (Dubois *et al*., 1956). Total soluble phenols were estimated using the Folin-ciocalteau colorimetric method (Swain and Hillis, 1959). Carotenoids contents (mg g-1 fresh leaves) were estimated adopting the procedure given by Arnon (1949). Ascorbic acid content (mg/100 g leaf fresh weight) was determined by titration. Total soluble carbohydrates as determined in leaves (fifth leaf) of three plants from each plot according to Dubois *et al.* (1956)

The proline content (mg/ g dry weight) was determined according to the methods of Bates *et al*. (1973) where 100 mg of lettuce leaf sample is taken and homogenized in 3% sulfosalicylic acid. After that, the homogenate is filtered through Whatman no.1 filter paper and 2 ml of the filtrate is taken with 2 ml of ninhydrin solution plus 2 ml of glacial acetic acid to obtain a final volume of 6 ml. The mixture is incubated at 100°C in heating water bath for one hour. By adding ice and 4 ml of toluene the reaction has stopped. Finally the mixture is shaken vigorously for 20-30 sec and the aqueous toluene layer is separated. The red color is measured at 520 nm wavelength of light. The concentration of proline in each sample is calculated by putting the absorbance in each sample against standard curve. The proline content is expressed as per the following formula :(proline (µg/ml) ×ml of Toluene)/115.5) × (5/gram of sample).

Leave Evaluation of head color:

Among the several existing color scales, CIELAB color space is a three -dimensional spherical system was defined by three colorimetric coordinates by using Minolta Chroma Meter (USA). The coordinate L* is called the lightness. The coordinate a* defines the deviation from the achromatic point corresponding to red when it is positive and to green if negative. Similarly, the coordinate b* defines the turning to yellow if positive and to blue if negative. Five lettuce heads from each plot were taken to measure the color values. Three reading were taken from each head from three places and then the average was calculated.

Statistical analysis:

The obtained data were statistically analyzed following the procedure of the analysis of variance (Snedecor and Cochran, 1980).Data of each season, separately ,were subjected to analysis of variance then the homogeneity of error variances was tested. Means of the treatments were compared using the Least Significant Difference (LSD) test at 0.05 probability level.

RESULTS AND DISCUSSION

Effect of water stress and salicylic acid on lettuce vegetative characters:

Data (in Table 1) showed that, regarding main vegetative characteristics of the Big bell cv, the root length was short for plants of both untreated with SA treatments (plants exposed to water stress at different two ages or control) comparing with those which sprayed with SA. Plants that were subjected to drought stress at age of 30 and treated with SA at different levels gave significantly greater values for root length in both seasons. Plants sprayed with SA at level of 200ppm having heaviest values for root weight but differences were not significant with treatment of SA at level of 100ppm in the two different stages of growth. Head diameter displayed a significant augmentation in the second year for the plants sprayed with SA at level of 200ppm at age of 30, while with no differences with those which treated with SA at level of 100ppm at the same age in the first year of study. Results showed the response of lettuce plant to water stress and the effect of salicylic acid on growth parameters. A remarkable difference in growth traits was observed between the treatments of water stressed and SA water-stressed. Plant growth characteristics were significantly reduced by water deficit. The growing lettuce plants affected with foliar spraying salicylic acid in different concentrations; whereas, the vegetative characteristics significantly affected with the differences of salicylic acid concentrations at both stages during the two seasons of this study. The best results were given when foliar application with SA at the level of 200ppm was done to plants that exposed to water deficit at age of 30 by withholding water for 15 days, followed with the treatment of spraying SA at the levels of 100ppm at same age, control treatment, and then the group which was sprayed with SA at the level of 200ppm at the age of 20 respectively. The lowest results were conjoined with the treatment under water stressed at age of 20 by withholding water for 15 days. The interaction between the time of applying drought stress treatments and salicylic acid concentrations appeared to be insignificant for most the studied vegetative characteristics except when SA sprayed at 200ppm at the age of 30 during the two seasons of this study. This result means that the water stressed treatments acted uniformly with spraying salicylic on the growing lettuce plants regarding to all the studied vegetative characteristics. It could be concluded that there were decline for the vegetative growth traits with increasing the water stress at earlier stage of growth (at age of 20) than the later stage (at age of 30). These results are in agreement with the results of Ahmad et al., (2014). The author reported that plant growth characteristics were significantly reduced by water stress which corresponds to the low water potential induced by the 7 days water deficit. Khan *et al.,* (2015) reported that salicylic acid played an important role in the regulation of certain processes in plants exposed to stress, thus enhancing the growth and development. Reduction in vegetative parameters of Lettuce under drought conditions might be related to suppression of cell expansion and cell growth due to leaf senescence under drought stress. The reduction in vegetative growth parameters under drought conditions in various crops has already been reported (Rane et al. 2001; Bhatt et al. 2005). Under drought stress, limiting of growth was occurred due to reduction of CO_2 fixation and $NADP^+$ regeneration of the Calvin cycle thus, leading to an over reduced in photosynthetic electron transport chain (Kalra, 1995).

Table 1. Influence of drought stress and salicylic acid (SA), treatments on growth characters of lettuce crop in 2018-2019 and 2019-2020 seasons respectively[(1)]

Treatments	SA Concentrations(ppm)	Root length(cm) 2018-2019	Root length(cm) 2019-2020	Root weight(g) 2018-2019	Root weight(g) 2019-2020	Head diameter(cm) 2018-2019	Head diameter(cm) 2020-2019
Drought stress at age of 20	0	7.000 C	7.767 CD	14.76 D	19.56 D	24.80 D	25.43 DE
	100	9.833 AB	8.667 BC	23.14 ABC	26.85 BC	25.52 CD	26.58 CD
	200	9.833 AB	9.667 AB	26.94 AB	27.69 AB	27.19 BC	28.46 BC
	300	7.333 C	7.867 C	17.55 CD	22.68 CD	24.92 D	26.21 DE
Drought stress at age of 30	0	7.833 C	6.533 D	17.44 CD	20.71 D	24.67 D	24.28 E
	100	10.50 AB	10.00 A	21.54ABCD	30.17 AB	28.68 AB	29.59 B
	200	10.17 AB	10.00 A	27.45 A	31.73 A	29.26 A	31.89 A
	300	10.83 A	10.00 A	20.21 BCD	22.08 D	26.12 CD	26.27 CDE
Control[2]	0	9.333 B	8.333 C	20.95ABCD	22.85 CD	26.71 BCD	27.11 CD
LSD 0.05		1.430	1.328	6.833	4.530	2.055	2.206

(1) means within column followed by the same letter(s) are not significantly different at 0.05 level of probability

(2) Control(supplying water at regular intervals)

Effect of water stress and salicylic acid on lettuce yield characters:

The statistical analysis showed that drought stress and application of SA had a significant effects on yield and quality characteristics of the lettuce plants (Table 2). Results showed that drought stress imposed negative effects on plant productivity. The effect of water stress at earlier stage of growth (at age of 20) was more inhibitory as compared to that of later stage (at age of 30). Plants that treated with SA exhibited an increase in tolerance to water stress. Plants that exposed to drought stress and treated with 200ppm SA had heavier head fresh weight in both years than plants derived from control treatment or plants that not treated with SA. Head dry weight traits, significantly affected with the water deficit treatments during the first and second seasons. Plants subjected to water stress at age of 30 and treated with 200ppm SA produced higher total yield than either control treatment or plants subjected to water stress and not sprayed with SA. Therefore, Salicylic acid (SA) is responsible for inducing defense mechanisms in plants and also plays the main role in protection under stress conditions. The reduction of fresh weight under water stress in different crops has already been reported (Bhatt *et al.* 2005). Reduction in fresh and dry weight of Lettuce plants under water stress conditions might be due to suppression of cell expansion and cell growth and also more leaf senescence under water stress.

Table 2. Influence of drought stress and Salicylic acid (SA), treatments on yield characters of lettuce crop in 2018- 2019 and 2019-2020 seasons respectively [(1)]

Treatments	SA Concentrations(ppm)	Head fresh weight(g) 2018-2019	Head fresh weight(g) 2019-2020	Head dry weight(g) 2018-2019	Head dry weight(g) 2019-2020	Total yield (ton/fed.) 2018-2019	Total yield (ton/fed.) 2020-2019
Drought stress at age of 20	0	381.5 EF	436.0 D	23.93 E	27.34 E	10.90 EF	12.46 D
	100	452.8 CDE	517.3 BC	30.22 D	34.53 BC	12.94 CDE	14.78 BC
	200	505.1 BCD	560.7 B	33.38 CD	37.05 B	14.43 BCD	16.02 B
	300	423.7 DE	467.9 CD	29.69 D	32.78 CD	12.11 DE	13.37 CD
Drought stress at age of 30	0	310.4 F	351.7 E	14.52 F	16.45 F	8.868 F	10.05 E
	100	556.9 AB	569.7 B	37.17 BC	38.02 B	15.91 AB	16.28 B
	200	633.0 A	667.4 A	41.83 AB	44.11 A	18.09 A	19.07 A
	300	430.0 DE	428.6 D	30.13 D	30.03 DE	12.29 DE	12.24 D
Control[2]	0	535.1 BC	525.8 B	46.99 A	46.17 A	15.29 BC	15.02 B
LSD 0.05		84.47	55.55	5.728	3.533	2.413	1.587

(1) means within column followed by the same letter(s) are not significantly different at 0.05 level of probability

(2) Control(supplying water at regular intervals)

Effect of water stress and salicylic acid on Photosynthetic pigments (chlorophyll a, b, total and carotenoids) content:

The current results (in Table 3) revealed that application of water stress to the plants decreased the values for chlorophyll a, b and total chlorophyll contents compared to control treatment. The plants subjected to water deficit exhibited a significant decline in photosynthetic parameters. Plants treated with salicylic acid resulted in significantly increased chlorophyll a, b and total in comparison to either control treatment or those from under stress and untreated plants. Plants receiving salicylic acid (SA) at 200 pm overcome the adverse effects generated by water stress either at earlier or later stages of growth. Foliar application of salicylic acid was found to increase the chlorophyll content in many crops such as Cucumber (Yildirim *et al*., 2008) and strawberry (Jamali *et al*., 2011).Also, the incensement of carotenoids was found as the result of foliar spray with salicylic acid. Foliar application of SA at concentration of 200ppm at both stages resulted to a significant increase in carotenoids content in both seasons of study. This is in agreement with the findings by (Turkyılmaz *et al*. 2005) in bean plants.SA regulates physiological and biological processes in plants and can be used as a potential growth regulator to enhance plant growth, but the efficiency of exogenous SA depends on several causes such as the developmental stage, and SA concentration (Borsani *et al*., 2001).

Table 3. Influence of drought stress and Salicylic acid (SA), treatments on Photosynthetic pigments (chlorophyll a, b, total and carotenoids) content of lettuce crop in 2018- 2019 and 2019-2020 seasons respectively(1)

Treatments	SA concentrations	chll a (mg/g)		chll b (mg/g)		chll total (mg/g)		Carotenoids	
		2018-2019	2020-2019	2018-2019	2019-2020	2018-2019	2019-2020	2018-2019	2020-2019
Drought stress at age of 20	0	0.2270 G	0.2227 G	0.09633 G	0.06300 F	0.3233 G	0.2857 G	0.1663 G	0.1740 G
	100	0.2810 E	0.2737 E	0.1720 E	0.1757 D	0.4530 E	0.4493 E	0.2470 D	0.2510 D
	200	0.7333 A	0.7243 A	0.3740 A	0.3700 A	1.107 A	1.094 A	0.5910 A	0.5880 A
	300	0.5580 C	0.5520 C	0.2853 C	0.2957 B	0.8433 C	0.8477 C	0.3260 C	0.3320 C
Drought stress at age of 30	0	0.2397FG	0.2393FG	0.1450 F	0.1420 E	0.3847 F	0.3813 F	0.2027 F	0.2030 F
	100	0.4017 D	0.4020 D	0.2430 D	0.2380 C	0.6447 D	0.6400 D	0.2560 D	0.2593 D
	200	0.7343 A	0.7247 A	0.3760 A	0.3707 A	1.110 A	1.095 A	0.5913 A	0.5980 A
	300	0.5983 B	0.5950 B	0.3140 B	0.3110 B	0.9123 B	0.9060 B	0.4963 B	0.4990 B
Control[2]	0	0.2453 F	0.2453 F	0.1553 EF	0.1497 E	0.4007 F	0.3950 F	0.2250 E	0.2220 E
LSD 0.05		0.02998	0.005474	0.03462	0.1974	0.1815	0.1224	0.007741	0.1896

(1) means within column followed by the same letter(s) are not significantly different at 0.05 level of probability

(2) Control(supplying water at regular intervals)

Effect of water stress and salicylic acid on Carbohydrates, total sugar, ascorbic acid content, proline and total phenolic:

Plants subjected to drought stress gave significantly lower values for carbohydrates content than that supplying water at regular intervals (control). However, plants which sprayed with SA at the level of 300ppm at the age of 30 gave significantly the highest values for carbohydrates content. The high concentrations of SA was more efficient than the low concentrations of SA in this regard (Table 4).

Foliar application with SA at the level of 300 ppm exhibited significant increases regarding total sugars and ascorbic acid content. Proline and content total phenolic in water-stressed plants were significantly higher than non-water-stressed plants. The contents of proline and total phenolic in SA-treated plants under drought stress were significantly higher than both of non- stressed plants (control) and that of stressed plants without spraying with SA. In this experiment foliar application of SA increased proline levels in lettuce plants. Data showed that proline content in leaves increased as SA concentrations increased. Plants reduce the negative effect of drought stress by different ways, such as accumulation inorganic ions, soluble sugars and proline.

Table 4. Influence of drought stress and Salicylic acid (SA), treatments on Carbohydrates, total sugar , ascorbic acid content, proline and total phenolic of lettuce crop in 2018- 2019 and 2019-2020 seasons respectively(1)

Treatments	SA Concentrations (ppm)	Carbohydrates (mg/g)		Total sugar		Ascorbic acid content (mg/100 g leaf fresh weight)		proline (µm/g FW)		total phenolic (mg/g)	
		2018-2019	2019-2020	2018-2019	-2019 2020	2018-2019	2019-2020	2018-2019	2019-2020	2018-2019	-2019 2020
Drought stress at age of 20	0	1.660 I	1.733 I	3.731 F	3.109 H	5.207 B	4.897 B	9.500 F	7.467 F	0.2820 E	0.2893 E
	100	3.610 F	3.927 F	4.125 E	4.173 E	4.903 D	4.703 B	14.60 D	15.23 D	0.3123 D	0.3037 E
	200	4.520 D	4.760 D	4.779 D	4.650 C	5.103 C	5.403 A	20.87 B	21.77 B	0.4793 B	0.5667 B
	300	4.953 C	5.090 C	5.620 B	5.103 B	5.103 C	5.603 A	24.23 A	25.07 A	0.7173 A	0.6860 A
Drought stress at age of 30	0	2.793 H	2.513 H	3.780 F	3.480 F	4.607 E	3.957 C	4.867 G	5.200 G	0.2720 E	0.2630 F
	100	4.103 E	4.147 E	3.398 G	4.500 D	5.223 B	5.313 A	11.47 E	12.77 E	0.2890 E	0.2893 E
	200	5.070 B	5.350 B	5.131 C	4.643 C	5.293 B	5.403 A	15.47 D	15.83 D	0.3263 D	0.3417 D
	300	6.073 A	6.152 A	6.345 A	6.753 A	5.717 A	5.567 A	18.00 C	18.90 C	0.3450 C	0.3803 C
Control[2]	0	3.063 G	3.403 G	3.899 F	3.213 G	4.307 F	4.107 C	3.667 H	4.367 G	0.2513 F	0.2590 F
LSD 0.05		0.01731	0.1224	0.1896	0.05474	0.09481	0.2998	1.047	1.301	0.01731	0.02448

(1)means within column followed by the same letter(s) are not significantly different at 0.05 level of probability

(3) Control(supplying water at regular intervals)

Therefore, the accumulation of these molecules considered as physiological indicators in overcome water stress tolerance (Farooq *et al*., 2009).Thus increasing of proline in plants under drought stress decreases adverse effects of stress. Accumulation of proline in plants is considered as an indication of disturbed physiological conditions triggered by abiotic or abiotic stress conditions. Free proline content increase when plants expose to stress. Yazdanpanah *et al*. 2011 reported that SA application declined adverse effect of drought by increasing sugar and proline accumulation in plants. Many studies supported a great role of SA in modulating the plant response to several abiotic stresses including drought (Senaratna *et al*., 2000; Yazdanpanah *et al*., 2011). Osmotic adjustment is an important metabolic processes in plant adaptation to water deficit stress as it synthesis and accumulates small compatible solutes such as proline and sugars (Chaves at al., 2003).

Effect of water stress and salicylic acid on color measurements *(a, b and L) of Lettuce head color:

Data (in Table 5) indicate that, the highest value of L (lightness) was obtained from control treatment in first season and by using SA 200 ppm at the age of 20 in second season. b* values ranged from 18.89 to 30.20 (medium green color) and there were significant differences among treatments . Plants that exposed to drought stress at the age of 20 and sprayed with SA at 200 ppm gave the highest value regarding b*followed by that exposed to drought stress at the age of 30 and sprayed with SA at 200 ppm.

Table 5. Influence of drought stress and Salicylic acid (SA), treatments on color measurements *(a, b and L) of Lettuce head color in 2018- 2019 and 2019-2020 seasons respectively (1)

Treatments	SA concentrations	L		A		b		Cl	
		2018-2019	2020-2019	2018-2019	2019-2020	2018-2019	2019-2020	2018-2019	2020-2019
Drought stress at age of 20	0	44.53 F	45.87 G	-11.07 B	-11.93 B	19.51 DE	19.14 G	20.28 B	21.23 B
	100	46.82 D	48.22 F	-10.83 B	-12.84 C	19.23 EF	22.48 C	21.64 A	21.17 B
	200	49.97 B	52.52 A	-11.07 B	-14.85 F	28.30 A	29.21 A	15.10 F	17.75 D
	300	47.45 C	49.32 D	-9.980 A	-12.07 B	19.18 EF	20.19 E	20.13 B	21.43 B
Drought stress at age of 30	0	47.62 C	49.87 C	-10.93 B	-12.73 C	18.89 F	19.52 FG	19.23 C	20.23 C
	100	45.96 E	48.84 E	-9.550 A	-10.43 A	20.38 C	21.18 D	17.80 D	17.47 D
	200	46.61 D	48.85 E	-10.72 B	-13.44 D	23.82 B	27.35 B	17.01 E	17.52 D
	300	47.83 C	50.86 B	-10.84 B	-14.39 E	20.22 C	19.23 FG	19.11 C	22.97 A
Control[2]	Without stress or SA	51.79 A	49.16 DE	-11.13 B	-12.84 C	19.72 D	19.65 F	17.33 E	20.57 C
LSD 0.05		0.4345	0.4547	1.406	0.4677	0.4447	0.4612	0.4379	0.4644

(1) means within column followed by the same letter(s) are not significantly different at 0.05 level of probability
(2) Control(supplying water at regular intervals
***Means of 15 heads per treatment using Minolta Chroma Meter CR- 400. (L= lightness, a= red to green, b=yellow to blue)**

CONCLUSION

Water stress has been recognized as a big threat to plant survival. Plants therefore induce several physiological, biochemical processes and molecular mechanism to survive these threats. In this study,we observed that water stress decreases lettuce yield. Salicylic acid is a compound capable of reducing and mitigating the negative effects of the stress. Overall, 200 ppm exogenous application of salicylic acid proved to be more effective to overcome the adverse effects of drought stress on *Lactuca sativa* L.Fliar application of salicylic acid not only enhances yield production but also improving quality characteristics in lettuce.

REFERENCES

Ahmad, MA; Murali, PV; Marimuthu, G (2014). Impact of salicylic acid on growth, photosynthesis and compatible solute accumulation in Allium cepa L. Subjected to drought stress. Int Jour of Agric and Food Sci 4(1): 22-30.

Arfan, M., A. Habib and M. Ashraf. 2007. Does exogenous application of salicylic acid through the rooting medium modulate growth and photosynthetic capacity in two differently adapted spring wheat cultivars under salt stress J. Plant Physiol., 164(6): 685- 694.

Arnon, D.I., 1949. Copper enzymes in isolated chloroplast. Polyphenol-oxidase in Beta vulgaris L. Plant Physiol., 24: 1-5

Bates, L, R. P. Waldren and I.D.Teare. (1973). Rapid determination of free proline for water stress studies. Plant Soil.39:205-207.

Bhatt RM, Srinivasa-Rao NK. 2005. Influence of pod load on response of okra to water stress. Indian J Plant Physiol 10, 54-59.

Borsani O, Valpuesta V, Botella MA. 2001. Evidence for a role of salicylic acid in the oxidative damage generated by NaCl and osmotic stress in Arabidopsis seedlings. J Plant Physiol 126, 1024-1030.

Chaves, MM; Maroco, JP; Pereira, JS (2003). Understanding plant responses to drought from genes to the whole plant. Functional *Plt Biol* 30: 239–264.

Dat, J. F., C. H. Foyer and I. M. Scott, 1998a. Changes in salicylic acid and antioxidants during induced thermo tolerance in mustard seedlings. Plant Physiol. 118: 1455–1461.

Dat, J. F., H. Lopez-Delgado, C. H. Foyer and I. M. Scott, 1998b. Parallel changes in H2O2 and catalase during thermo tolerance induced by salicylic acid and heat acclimation of mustard seedlings. Plant Physiol. 116: 1351–1357.

Dubois, M., F. Smith, K.A. Gilles, J.K. Hamilton and P.A. Rebers, 1956. Colorimetric method for determination of sugars and related substances. Analytical Chemistry, 28 (3): 350-356.

Farooq M, Wahid A, Kobayashi N, Fujita D, Basra SMA(2009).Plant drought stress effects, mechanisms and management,Agron.Sustain.Dev.29:185-212.

Fita, A., F. Fioruci, M. Plazas, A. Rodriguez-Burruezo, and J.Prohens.2015.Drought-Toleranceamong Accessions of Eggplant and Related Species. Bulletin UASVM Horticulture 72(2):461-462.

Hasan, A.A. (1991).Production of vegetable crops.1st ed., Published by Arab House for publishing and Distribution, Cairo, Egypt. (in Arabic).

Hayat, Q., Hayat, S., Irfan, M. and Ahmed, A. (2010).Effect of exogenous salicylic acid under changing environment: A review. Environ. Exp. Bot., 681, 14-25. DOI: 10.1016/j.envexpbot.2009.08.005

Horva´th, E., M. Pa´l, G. Szalai, E. Pa´ldi and T. Janda, 2007. Exogenous 4-hydroxybenzoic acid and salicylic acid modulate the effect of short-term drought and freezing stress on wheat plants. Biol. Plant. 51: 480–487.

Jamali, B., Eshghi,S., and E., Tafazoli, 2011. Vegetative and Reproductive Growth of Strawberry Plants cv.'Pajaro'Affected by Salicylic Acid and Nickel.Journal of Agricultural Science and Technology 13(6):895-904

Kalra, YP (1995). Determination of pH of Soils by Different Methods: Collaborative Study. J.AOAC Inter. *78*(2): 310-323

Kawano, T., Furuichi , T. and Muto, S.(2004). Controlled salicylic acid levels and corresponding signaling mechanisms in plants. Plant Bio technol., 21(5), 319-335. DOI: 10.5511/plantbiotechnology.21.319.

Khan, MIR; Fatma, M; Per, TS; Anjum, NA; Khan, NA (2015). Salicylic acid-induced abiotic stress tolerance and underlying mechanisms in plants. *Front. Plant Sci*. 6:46-52

Lopez – Orenes, A., Martinez-Moreno, J. M., Calderon, A. A., and Ferrer, M.A. (2013) changes in phenolic metabolism in salicylic acid-treated shoots of Cistus heterophyllus. Plant Cell Tiss. Organ Cult. , 113, 417-427. DOI: 10. 1007/s11240-012-0281-z

Masarirambi, M.T., P. Dlamini, P.K. Wahome and T.O. Oseni, 2012. Effects of chicken manure on growth, yield and quality of lettuce (Lactuca sativa L.) 'Taina' under a lath house in a semi-arid sub-tropical environment. American-Eurasian Journal of Agricultural and Environmental Science. 12399.

Nicolle C., Carnat A., FraIsse D., Lamaison J .L, Rock E., Michel H . , Amouroux P., Remesy Ch.,(2004). Characterization and variation of antioxidant micronutrients in lettuce (Lactuca sativa folium). J. Sci. Food Agric. 84: 2061-2069.

Nielson, D.C. and N.O. Nelson, 1998. Black bean sensitivity to water at various growth stages, Crop Sci., 38: 422-427.

Norman, J.C., 1992. Tropical Vegetable Crops, Arthur H.Stockwell Ltd, United Kingdom

Peng, L. and Yueming, J. (2006). Exogenous salicylic acid inhibits browning of fresh-cut Chinese water chestnut. Food Chem., 94, 535-540. DOI: 10.1016/j.foodchem. 2004.11.047

Rane J, Maheshwari M, Nagarajan S. 2001. Effect of preanthesis water stress on growth, photosynthesis and yield of six wheat cultivars differing in drought tolerance. Indian J Plant Physiol 6, 53-60.

Raskin, I (1992). Role of salicylic acid in plants. Ann Rev of Plt Physiol and Plt Mol Biol 43: 439- 463

Senaratna, T., D. Touchell, E. Bunn and K. Dixon, 2000. Acetyl salicylic acid and salicylic acid induce multiple stress tolerance in bean and tomato plants. Plant Growth Regul. 30:157–161.

Singh, B. and K. Usha, 2003. Salicylic acid-induced physiological and biochemical changes in wheat seedlings under water stress. Plant Growth Regul. 39: 137–141.

Snedecor, C.W. and W.G. Cochran. 1980. Statistical methods. 6th ed. Iowa Univ. Press, Ames, Iowa, U.S.A

Stevens J, Senaratna T, Sivasithamparam K. 2006. Salicylic acid induces salinity tolerance in tomato (*Lycopersicon esculentum* cv. Roma): Associated changes in gas exchange, water relations and membrane stabilisation.Plant Growth Regul 49, 77-83.

Swain, T. and W.F. Hillis, 1959. The quantitative analysis of phenolic constituent. Journal of Science and Food Agricultural, 10: 63-69.

Türkyılmaz B, Aktaş LY, Güven A. 2005. Salicylic acid induced some biochemical and physiological changes in Phaseolus vulgaris L. Science and Engineering Journal of Firat Univ 17(2), 319-326.

Yazdanpanah, S., A. Baghizadeh and F. Abbassi, 2011. The interaction between drought stress and salicylic and ascorbic acids on some biochemical characteristics of Atureja hortensis African Journal of Agricultural Research 6: 798-807.

Yildirim E., M. Turan and I.Guvenc, 2008. Effect of Foliar Salicylic Acid Applications on Growth, Chlorophyll, and Mineral Content of Cucumber Grown Under Salt Stress. Journal of Plant Nutrition 31(3):593-612.

حمض السلسليك يحسن النمو والمحصول والجودة لنباتات الخس المنزرعة تحت ظروف الاجهاد المائى

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اجريت هذة الدراسة بمزرعة التجارب البحثية – كلية الزراعة – جامعة القاهرة وذلك خلال عامى 2019/2018، 2020/2019 .وتم دراسة تأثير 4 معاملات لحمض السلسليك على نباتات الخس المزروعة تحت ظروف الاجهاد المائى(ايقاف الرى لمدة 15 يوما) عند عمر 30،20 يوم من الشتل بالاضافة الى معاملة الكنترول والتى تم الرى فيها بانتظام.وكانت المعاملات المستخدمة من حمض السلسليك 300،200،100،0 جزء فى المليون وذلك تحت ظروف ايقاف الماء عند العمرين المذكورين سابقا بالاضافة الى معاملة الكنترول. وقد اشارت النتائج الى ان النباتات التى تم ايقاف الرى لها عند عمر 30 يوم من الشتل ومعاملتها بحمض السلسليك بتركيز 200 جزء فى المليون هى الافضل،فاعطت افضل طول ووزن للجذر ايضا اعطت اعلى القيم لقطر الرأس والاعلى فى المحصول حيث سجلت المعاملة زيادة فى المحصول بمقدار 18,3% و26.9%خلال موسمى الزراعة على التوالى مقارنة بمعاملة الكنترول والنى يتم فيها الري بانتظام .كما سجلت هذة المعاملة اعلى القيم للمحتوى من الكلورفيل والكاروتين.اما بالنسبة لمحتوى الاوراق من حمض الاسكوربيك والبرولين والسكريات والفينولات الكلية فقد سجلت النباتات المعرضة لظروف الاجهاد المائى عند عمر 20 يوما من الشتل والمعاملة بحمض السلسليك بتركيز 300 جزء فى المليون اعلى القيم. ومع وجود مشكلة فى جودة وانتاج الخس تحت ظروف الاجهاد المائى،فان هذة الدراسة تقدم طريقة لزيادة المحصول وتحسين الجودة فى الخس المزروع تحت مثل هذة الظروف.