Zagazig J. Agric. Res., Vol. 47 No. (6) 2020 1407-1421

Plant Production Science

Available online at http://zjar.journals.ekb.eg
http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

ALLEVIATING SOIL SALT EFFECTS ON SAGE (*Salvia officinalis*, L.) PLANTS BY SALICYLIC ACID AND HUMIC ACID FOLIAR APPLICATIONS

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Received: 16/08/2020 ; Accepted: 18/10/2020

ABSTRACT: In order to record the response of sage plants to foliar spray with salicylic acid (SA) and humic acid (HA) under soil salinity conditions, two pot experiments in lath house were conducted at the Nursery of Ornamental Plants, Agric. Fac., Zagazig Univ., Sharkia Governorate, Egypt during the two winter consecutive seasons of 2018/2019 and 2019/2020. To study the effect of salicylic and humic acids on salinity tolerant ability of sage plants, different treatments were used as control (sprayed with water), salicylic acid (SA) at 200 ppm, humic acid (HA) at 750 ppm as well as 1500 ppm HA, 200 ppm SA+750 ppm HA and 200 ppm SA+1500 ppm HA under different soil salinity levels (0.0, 1000 and 2000 ppm) as well as their combinations on growth, yield components, salt resistance index and total chlorophyll content. This experiment was set up in a split-plot design with three replicates. The main plots were occupied by soil salinity levels and the sub plots were entitled to SA and HA acids concentrations. Plant height (cm), branch number/plant, fresh and dry weights of roots/ plant (g), root length (cm) and No. of roots/plant as growth parameters, also yield weights of fresh and dry herb/ plant (g) as yield components as well as salt resistance index percentage were recorded. Also, total chlorophyll (SPAD unit) in the leaves was determined. Results showed that using soil salinity levels 1000 and 2000 ppm significantly decreased growth parameters, yield and total chlorophyll content compared to control. In addition, the maximum values of the above mentioned characters were obtained by treating plants with SA at 200 ppm + HA at 1500 ppm. Generally, it could conclude that SA at 200 ppm + HA at 750 or 1500 ppm, showed an influence in alleviating of sage growth inhibition and increasing salt resistance index under moderate salinity stress (1000 ppm level) saline condition.

Key words: *Salvia officinalis*, soil salinity, salicylic acid, humic acid, growth, yield, salt resistance, chlorophyll.

INTRODUCTION

Medical and aromatic plants have been fundamental components of healthcare over human history (**Schippmann *et al*., 2002**). Sage (*Salvia officinalis*, L.) is an herbaceous and perennial plant belongs to family Labiatae and is native to Mediterranean region and currently cultivated in dry areas of Europe, North Africa, America and Asia. Common sage (salvia) is one of the most important medicinal and aromatic plants, with spasmolytic, antioxidant, astringent, anti hidrotic, antimicrobial, and specific sensorial attributes (**Yadegari and Shakerian, 2014**). As recognized, the plant growth, yield and the biosynthesis of chlorophyll influenced by various environmental factors namely the foliar spraying with salicylic and humic acids (**Khan *et al*., 2003; Peña-Méndez *et al*., 2005**), and soil salinity level (**Solinas and Deiana, 1996**). This biotic constraint is found to convert growth and yield and quality in several species (**Karimian *et al*., 2019; Es-Sbihi *et al*., 2020**).

Soil salinity stress negatively influences plant development, growth and yield due to the effects, nutritional imponderables, and low osmotic prospect of soil solution and incorporations of these agents (**Ashraf and Harris, 2004**). The high salinity of the soil influenced the soil penetration, reduced the soil

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water potential and lastly caused physiological dehydration (**Yusuf *et al*., 2008**). Under salinity condition changes the plants metabolisms to cope the changed environmental conditions. One mechanisms used by the plants for overcoming the salt stress impacts might be by means of accumulation of proper osmolytes, such as soluble sugar and proline. Accumulation of free amino acids and production, particularly proline by plant tissue during salt and water stress is an adaptive response (**Kamel *et al*., 2011**).

Salicylic acid (SA) is a phenolic compound in plant and today it is in utilize as interior regulator hormone, in order to its function in the defensive mechanization versus biotic and abiotic stresses has been assured (**He *et al*., 2005**). The exogenous application of SA has been notified to encourage tolerance to salt stress (**Jayakannan *et al*., 2015**). SA mitigated the inverse influence of high salinity by lessening K+ leakage from tissues of root and by promoting the H+-ATPase activity (**Jayakannan *et al*., 2013**), which supplies a driving force for Na+/H+ exchanger at the plasma membrane and leads to decreased Na accumulation in the cytosol (**Shi *et al*., 2000**).

There are direct and indirect influences on plant growth because of various functions of humic (**Pal and Biswas, 2005**). Humic acid (HA) treatments get better soil aggregation, structure, air conditioning, water permeability, fertility, moisture holding capacity, and raises microbial action of microbial population and cation interchange capacity (**Mohamed, 2012**). In addition, they are responsible for the growth parameters of stevia plants such as plant height, branch number/plant and total dry weight/plant as well as total chlorophyll content and they are included in some biological process such as the production of plant development-impacts substances as free enzymes (**Mohammed *et al*., 2019 b**).

In this study, we noticed and recorded the response during the growth of *Salvia officinalis* exposed to different levels of soil salinity and different concentrations of salicylic and humic acids as foliar spray. So, this study aimed to find the mitigating effect of salicylic and humic acids on growth, yield and salt resistance index of sage plants under salt stress.

MATERIALS AND METHODS

A preliminary experiment was carried out at 10th March 2018 on the effect of soil salinity levels (0.0, 1000, 2000 and 3000 ppm) on common sage plants. Only the growth and development of 0.0, 1000 and 2000 ppm levels was noticed, while plants died at a high soil salinity level (3000 ppm), therefore, the experiment was completed on the effect of soil salinity levels (0.0, 1000 and 2000 ppm) only. A lath house experiment was carried out at the Nursery of Ornamental Plants, Horticulture Department, Zagazig University, Sharkia Governorate, Egypt during the two winter consecutive seasons of 2018/2019 and 2019/ 2020. A total of 270 transplants [(3 soil salinity × 6 salicylic and humic acid treatments) × 3 replicates × 5 transplants) were transplanted into pots (30 cm diameter, 30 cm depth and 12 kg capacity) filled with a soil that its texture was sand: clay (1:1 *V/V*). The physical and chemical properties of the utilized soil mixture (average of the two seasons) are presented in Table 1 according to **Chapman and Pratt (1978)**. Attention had been driven to follow the changes in growth, root system, herb yield, salt resistance index and total chlorophyll content of sage (*Salvia officinalis*, L.) plants in order to obtaining results from applying salinity levels as well as SA and HA acids combination treatments.

This experiment was carried out utilizing a split-plot in complete randomized block design with three replications. The first factor (main plot) studied included three salinity levels (0.0, 1000 and 2000) that were used the certain amounts of sodium chloride in distilled water. The three levels of artificial soil salinity were used by dissolving the natural salt crust of sea water in distilled water then added to the soil based on its weight. The chemical analysis of salt is shown in Table 2. The second factor (sub plot) studied included six acids concentrations [control (sprayed with water), salicylic acid (SA) at 200 ppm, humic acid (HA) at 750 ppm, 1500 ppm HA, 200 ppm SA+750 ppm HA and 200 ppm SA+1500 ppm HA)] as foliar spray. The combination treatments between soil salinity level as well as SA and HA acids concentrations were consisted of 18 treatments.

Table 1. Physical and chemical properties of experimental farm soil (average of two seasons)

Physical analysis			Soil texture
Clay (%)	**Silt (%)**	**Sand (%)**	**Sandy**
22.37	7.93	69.70	

Chemical analysis														
Time	**pH**	**EC (dsm^{-1})**	**Soluble cations (m.mol/l)**					**Soluble anions (m.mol/l)**			**Available (ppm)**		
			Ca^{++}	Mg^{++}	Na^{+}	Zn^{++}	Mo^{++}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
Before planting	**7.80**	0.58	1.80	0.95	0.30	1.10	1.32	3.04	1.12	0.84	127	46	51

Table 2. Chemical analysis of salt (water-salt extract at 5:1)

EC (mmhos/cm)	Soluble cations (m.mol/l)				Soluble anions (m.mol/l)			
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	CO_3^{--}	SO_4^{--}	Cl^{-}
171.3	9.28	8.54	3000.0	2.80	4.86	0.0	80.76	2935.00

However, common sage plants were foliar sprayed with SA and HA acids concentrations four times at 30, 45, 60 and 75 days after planting date. The source of salicylic acid ($C_7H_6O_3$) was Techno Gene Company (TGC), Dokky, Giza, Egypt. Vegetarian humic acid fertilizer (Abo Zaabal Company to Fertilizers) contains 86% humic acid.

Seedlings of sage (salvia) were obtained from a Private Nursery in Belbeis District (called Mostafa Aboesa Nursery), Sharkia Governorate, Egypt and were sown on 1st October during 2018/2019 and 2019/2020 seasons. All seedlings were similar in growth and 10 cm in length. One seedling was planted per pot. All recommended agricultural practices of growing common sage plants were done whenever needed. The basal rates of nitrogen (N), phosphorous (P_2O_5) and potassium (K_2O) were applied in each pot at the rate of 140 mg/kg, 60 mg/kg and 40 mg/kg through ammonium sulphate (20.5% N), single superphosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O), respectively, at 35, 55 and 75 days of planting date.

Data Recorded

A random sample of three plants from each sub plot was taken at 88 and 125 days after planting for measuring plant growth and yield characters, respectively and the following data were recorded:

Plant growth

At 88 days after planting date, plant height (cm), number of branches, fresh and dry weights of roots/plant (g) as well as number of roots per plant and root length (cm) was recorded.

Yield and its components

Fresh and dry herb yield (dried in oven at 45ºC) per sage plant were determined at 125 days of planting date in the two seasons.

The salt resistance index (SRI %)

At 125 days after planting as a real indicator for salinity tolerance was calculated from the equation mentioned before by **Chen *et al*. (2007)** SRI (%) = Mean fresh herb yield per plant of the salt treated plants/mean fresh herb yield per plant of control one × 100.

Total chlorophyll content (SPAD)

In fresh leaf samples of existing sage plants at 88 days after planting date during both seasons, total chlorophyll content (SPAD unit) was measured by using SPAD- 502 meter as described by **Markwell *et al*. (1995)**.

Statistical Analysis

Data of the present study were statically analyzed according to **Gomez and Gomez (1984)** and the differences between the means of the treatments (salinity levels and SA and HA acids concentrations) were considered significant when they were more than the least significant differences (LSD) at 5% levels by using computer program of Statistix Version 9 (**Analytical Software, 2008**).

RESULTS AND DISCUSSION

Growth Parameters

Effect of soil salinity level

Results presented in Tables 3 and 4 shows that, using the salinity level treatments (1000 and 2000 ppm) significantly decreased plant height and number of branches per sage plant compared to control (un-salinized plants) in both seasons. Similarly, fresh and dry weights of roots per sage plant as well as number of roots per plant and root length, significantly decreased when plants are grown in salinity soil compared to control (sprayed with distilled water) in the first and second seasons (Tables 5, 6, 7 and 8). In conclusion, increasing soil salinity levels significantly decreased *Salvia officinalis* growth parameters in 2018/2019 and 2019/2020 seasons.

Abiotic environmental stresses essentially salinity have the most effectiveness on aromatic and medicinal plants (**Heidari *et al*., 2008**). Salinity stress is one of the extreme harmful abiotic stress factors that impact the development, growth, productivity and physiology of plants. Various results were devoted from the influence of salinity stress on the quantitative and qualitative parameters. For example, it was reported that increasing of salinity stress reduced almost all the growth parameters in *Deracocephalum moldavica* (**Safikhani *et al*., 2007**), some growth parameters in *Matricaria chamomila* (**Razmjoo *et al*., 2008**). Growth parameters were noted to be repressed under salt stress in *Salvia officinalis*, *Ocimum basilicum*, *Coleus* species and *Rosmarinus officinalis* (**Ben Taarit *et al*., 2009**; **Said-Al Ahl *et al*., 2010**; **Kotagiri and Kolluru, 2017**; **Abdelkader *et al*., 2019**).

Effect of foliar spray with salicylic and humic acids concentrations

Results of both seasons in Tables 3 and 4 shows that, using all salicylic acid (SA) and humic acid (HA) alone or in combination treatments significantly increased plant height (cm) and number of branches per plant compared to control (unsprayed plants) in both seasons. The highest value in each of fresh and dry weights of root per plant, number of roots per plant and root length of common sage (*Salvia officinalis*) plants was obtained from 200 ppm SA+ 1500 ppm HA compared to control and the other ones under study during the two consecutive seasons (Tables 5, 6, 7 and 8). Whenever, the increases in number of branches per plant were about 38.27 and 62.98 % for the 200 ppm SA+ 1500 ppm HA treatment compared to control in the 1st and 2nd seasons, respectively.

There is a correlation between the beneficial effect of SA on the synthesis of secondary metabolites with advance in growth, photosynthesis and nutrient content (**Khanam and Mohammad, 2018**). Similar results were also found by **Es-Sbihi *et al.* (2020)** who reported that SA spraying on sage plants significantly increased stem and root growth. Furthermore, The positive influences of humic acid on cell membrane functions by elevating nutrient uptake, respiration, biosynthesis of ion absorption, nucleic acid, enzyme in order to they are hormone-like materials (**Yang *et al*., 2004**). HA used for plant nutrition, enhance development, root and plant growth as well as yield due to its action on physiological and metabolic procedures (**Eyheraguibel *et al*., 2008**). Moreover, **Said-Al Ahl *et al*. (2016)** reported that spraying by HA recorded the best results of plant height, number of branches and seed yield compared to control.

Table 3. Effect of soil salinity (S) and foliar spray with salicylic and humic acids (A) concentrations as well as their combinations (S×A) on plant height (cm) of *Salvia officinalis* at 88 days after planting during 2018/2019 and 2019/2020 seasons

Soil salinity level (ppm)	Salicylic acid (SA) and humic acid (HA) concentrations (ppm)						Mean (S)
	Control	200 SA	750 HA	1500 HA	200 SA + 750 HA	200 SA + 1500 HA	
				2018/2019 season			
Control	41.78	43.89	41.78	44.33	44.89	46.44	**43.85**
1000	33.11	35.00	34.56	37.33	38.11	39.67	**36.30**
2000	28.00	30.11	31.44	32.89	35.66	36.33	**32.41**
Mean (A)	**34.30**	**36.33**	**35.93**	**38.19**	**39.55**	**40.81**	
LSD at 5%	**For (S)= 0.60**		**For (A)= 0.46**		**For (S×A)= 0.93**		
				2019/2020 season			
Control	43.89	45.33	44.56	46.67	46.89	48.89	**46.04**
1000	31.11	34.11	35.22	38.56	40.33	40.78	**36.68**
2000	26.89	31.78	31.00	33.55	35.89	37.44	**32.76**
Mean (A)	**33.96**	**37.07**	**36.93**	**39.59**	**41.04**	**42.37**	
LSD at 5%	**For (S)= 0.45**		**For (A)= 0.45**		**For (S×A)= 0.84**		

Table 4. Effect of soil salinity (S) and foliar spray with salicylic and humic acids (A) concentrations as well as their combinations (S×A) on number of branches per plant of *Salvia officinalis* at 88 days after planting during 2018/2019 and 2019/2020 seasons

Soil salinity level (ppm)	Salicylic acid (SA) and humic acid (HA) concentrations (ppm)						Mean (S)
	Control	200 SA	750 HA	1500 HA	200 SA + 750 HA	200 SA + 1500 HA	
				2018/2019 season			
Control	11.56	11.89	12.00	13.78	14.67	15.89	**13.30**
1000	9.67	10.22	9.89	11.11	11.89	12.78	**10.93**
2000	7.56	8.67	9.34	10.11	10.56	11.11	**9.56**
Mean (A)	**9.59**	**10.26**	**10.41**	**11.67**	**12.37**	**13.26**	
LSD at 5%	**For (S)= 0.48**		**For (A)= 0.48**		**For (S×A)= 0.90**		
				2019/2020 season			
Control	10.56	11.89	12.34	15.11	15.78	17.89	**13.93**
1000	9.11	11.22	11.78	11.56	12.78	13.56	**11.67**
2000	6.11	9.78	9.33	8.33	9.78	10.56	**8.98**
Mean (A)	**8.59**	**10.96**	**11.15**	**11.67**	**12.78**	**14.00**	
LSD at 5 %	**For (S)= 0.21**		**For (A)= 0.30**		**For (S×A)= 0.51**		

Table 5. Effect of soil salinity (S) and foliar spray with salicylic and humic acids (A) concentrations as well as their combinations (S×A) on fresh weight of roots per plant (g) of *Salvia officinalis* at 88 days after planting during 2018/2019 and 2019/2020 seasons

Soil salinity level (ppm)	Salicylic acid (SA) and humic acid (HA) concentrations (ppm)						Mean (S)
	Control	200 SA	750 HA	1500 HA	200 SA + 750 HA	200 SA + 150 HA	
			2018/2019 season				
Control	9.61	9.90	10.14	11.01	12.07	12.80	**10.92**
1000	5.92	6.19	6.08	7.04	7.35	7.93	**6.75**
2000	3.86	4.28	4.41	4.80	4.92	5.76	**4.67**
Mean (A)	**6.46**	**6.79**	**6.88**	**7.62**	**8.11**	**8.83**	
LSD at 5%	**For (S)= 0.19**		**For (A)= 0.17**		**For (S×A)= 0.33**		
			2019/2020 season				
Control	7.99	8.05	9.60	9.92	11.90	12.35	**9.97**
1000	6.09	6.63	6.32	6.91	8.52	8.94	**7.24**
2000	4.04	4.58	4.35	4.47	5.05	5.47	**4.66**
Mean (A)	**6.04**	**6.42**	**6.76**	**7.10**	**8.49**	**8.92**	
LSD at 5%	**For (S)= 0.09**		**For (A)= 0.09**		**For (S×A)= 0.17**		

Table 6. Effect of soil salinity (S) and salicylic and humic acids (A) concentrations as well as their combinations (S×A) on dry weight of roots per plant (g) of *Salvia officinalis* during 2018/2019 and 2019/2020 seasons

Soil salinity level (ppm)	Salicylic acid (SA) and humic acid (HA) concentrations (ppm)						Mean (S)
	Control	200 SA	750 HA	1500 HA	200 SA + 750 HA	200 SA + 150 HA	
			2018/2019 season				
Control	2.94	3.39	3.73	4.06	4.41	4.81	**3.89**
1000	1.32	1.63	1.70	1.90	2.22	2.48	**1.88**
2000	0.95	1.10	1.19	1.29	1.42	1.87	**1.30**
Mean (A)	**1.74**	**2.04**	**2.21**	**2.42**	**2.68**	**3.05**	
LSD at 5%	**For (S)= 0.04**		**For (A)= 0.08**		**For (S×A)= 0.14**		
			2019/2020 season				
Control	2.42	2.64	3.24	3.65	4.11	4.32	**3.40**
1000	1.52	1.77	1.90	2.15	2.38	2.77	**2.08**
2000	1.11	1.24	1.10	1.17	1.55	1.72	**1.32**
Mean (A)	**1.68**	**1.88**	**2.08**	**2.32**	**2.68**	**2.94**	
LSD at 5%	**For (S)= 0.13**		**For (A)= 0.07**		**For (S×A)= 0.16**		

Table 7. Effect of soil salinity (S) and foliar spray with salicylic and humic acids (A) concentrations as well as their combinations (S×A) on number of roots per plant of *Salvia officinalis* at 88 days after planting during 2018/2019 and 2019/2020 seasons

Soil salinity level (ppm)	Salicylic acid (SA) and humic acid (HA) concentrations (ppm)						Mean (S)
	Control	200 SA	750 HA	1500 HA	200 SA + 750 HA	200 SA + 1500 HA	
				2018/2019 season			
Control	7.78	8.78	8.56	10.67	12.44	14.78	**10.50**
1000	5.00	6.78	6.67	7.33	9.22	9.45	**7.41**
2000	3.11	4.44	4.78	6.78	7.56	7.89	**5.76**
Mean (A)	**5.29**	**6.67**	**6.67**	**8.26**	**9.74**	**10.70**	
LSD at 5%	**For (S)= 0.31**			**For (A)= 0.43**		**For (S×A)= 0.75**	
				2019/2020 season			
Control	8.89	9.78	10.11	12.22	14.00	16.33	**11.89**
1000	5.78	6.56	7.33	7.89	10.33	11.78	**8.28**
2000	4.11	5.00	5.78	6.56	8.78	9.22	**6.57**
Mean (A)	**6.26**	**7.11**	**7.74**	**8.89**	**11.04**	**12.45**	
LSD at 5%	**For (S)= 0.48**			**For (A)= 0.40**		**For (S×A)= 0.79**	

Table 8. Effect of soil salinity (S) and foliar spray with salicylic and humic acids (A) concentrations as well as their combinations (S×A) on root length (cm) per plant of *Salvia officinalis* at 88 days after planting during 2018/2019 and 2019/2020 seasons

Soil salinity level (ppm)	Salicylic acid (SA) and humic acid (HA) concentrations (ppm)						Mean (S)
	Control	200 SA	750 HA	1500 HA	200 SA + 750 HA	200 SA + 1500 HA	
				2018/2019 season			
Control	12.89	16.33	18.55	20.44	22.11	23.89	**19.04**
1000	9.11	13.22	12.78	15.56	17.56	18.22	**14.41**
2000	6.22	6.89	8.00	7.89	9.89	11.22	**8.35**
Mean (A)	**9.41**	**12.15**	**13.11**	**14.63**	**16.52**	**17.78**	
LSD at 5%	**For (S)= 0.27**			**For (A)= 0.43**		**For (S×A)= 0.72**	
				2019/2020 season			
Control	10.89	14.89	13.89	19.45	22.89	25.56	**17.93**
1000	8.22	12.22	12.67	15.56	18.11	20.67	**14.74**
2000	6.78	8.78	9.45	10.56	11.78	13.22	**10.09**
Mean (A)	**8.63**	**11.96**	**12.00**	**15.52**	**17.59**	**19.82**	
LSD at 5%	**For (S)= 0.17**			**For (A)= 0.54**		**For (S×A)= 0.87**	

Effect of combination treatments between soil salinity and foliar spray with salicylic and humic acids concentrations

The results described in Tables 3, 4, 5, 6, 7 and 8 indicate that, all combination between soil salinity levels (1000 and 2000 ppm) and SA or/ and HA concentrations treatments significantly decreased sage growth parameters in both seasons. The control plants (without salinity application) which sprayed with SA at 200 ppm + HA at 1500 ppm resulted in the highest value for each of plant height, number of branches/ plant, fresh and dry weights of roots/plant, root number/ plant and root length in both seasons, followed by the combination treatment between that plants which sprayed with SA at 200 ppm + HA at 750 ppm. The decreases in plant height and number of branches per sags plant were about 13.04 and 14.70% as well as 3.89 and 0.00% for the combination between soil salinity at 2000 ppm + 200 ppm SA and 1500 ppm HA over control treatment (un-salinized plants + sprayed plants with tap water) in the 1st and 2nd seasons, respectively. Moreover, as mentioned above, both salicylic acid and humic acid increased growth parameters of sage (*Salvia officinalis*, L.) plant, in turn; they together under soil salinity conditions might maximize their influences leading to taller, more branches and heavier root per plant. These results are in line with those stated by **Esringü *et al*. (2015)** on *Impatiens walleriana* and **Es-Sbihi *et al*. (2016)** on *Mentha suaveolens* plants.

Yield Components

Effect of soil salinity level

The results illustrated in Tables 9 and 10 shows that, using soil salinity treatments significantly decreased fresh and dry herb weights per plant of sage compared to control in both seasons. In addition, sage yield was gradually decreased with increasing of the levels of salinity to reach its minimum by using that of 2000 ppm. The fresh and dry herb weights were significantly greater in control (71.47 and 74.23g as well as 18.78 and 20.16g), which was closely followed by 1000 ppm (63.66 and 66.19g as well as 15.70 and 16.07 g) in the 1st and 2nd seasons, respectively. The obtained results were parallel with those reported by **Taarit *et al*. (2009)** on common sage and **Ibrahim *et al*. (2019)** on sweet basil.

Effect of foliar spray with salicylic and humic acids concentrations

Furthermore, in most cases, salicylic and humic acids treatments significantly increased salvia fresh and dry herb weights per plant compared to untreated plants in the two seasons. SA at 200 ppm + HA at 1500 ppm significantly increased fresh and dry herb weights per plant compared to control and the other ones under study (Tables 9 and 10). Also, due to the effect of salicylic acid or humic acid and salicylic acid + humic acid, which penetrate rapidly into the plant tissues through the stomata and play vital roles in biological and physiological processes of *Salvia officinalis* which reflected on more yielded plants. Furthermore, **Safaei *et al*. (2014)** pointed out that different rates of humic acid imposed a significant effect on seed weight, seed and biological yields of black cumin plants compared to control. Also, **Mohammed *et al*. (2019a)** found that the maximum values of herb dry weight/ plant and air-dry weight of flower heads/plant were noticed when chamomile plants were applied with the highest rate of humic acid.

Effect of combination treatments between soil salinity and foliar spray with salicylic and humic acids concentrations

Results of both seasons in Tables 9 and 10 demonstrate that, the combination between soil salinity and SA and HA acids mostly decreased frsh and dry herb yield per sage plant comparing to control. Also, using 200 ppm SA + 1500 ppm HA increased yield components of common sage in comparison to the salinized plants under the same levels alone in the two consecutive seasons. Generally, the highest values in this connection were obtained from the combination treatment between 200 ppm SA + 750 ppm HA and without soil salinity application in both seasons. Whenever, the increases in fresh herb per plant were about 24.66 and 34.15% for application the 200 ppm SA+ 1500 ppm HA treatment under no salinity conditions compared to control in the 1st and 2nd seasons, respectively. In the same trend, **Khalil *et al*. (2018)** stated that the highest yield of *Thymus vulgaris* was obtained from drought stressed plants (25% FC) sprayed with 2 mM SA. In addition, **Desoky *et al*. (2019)** reported that application of humus component overcome the harmful influences of salinity stress on the of shoot fresh and dry weight Sudan grass compared with untreated plants.

Table 9. Effect of soil salinity (S) and foliar spray with salicylic and humic acids (A) concentrations as well as their combinations (S×A) on fresh weight of herb per plant (g) of *Salvia officinalis* at 125 days after planting during 2018/2019 and 2019/2020 seasons

Soil salinity level (ppm)	Salicylic acid (SA) and humic acid (HA) concentrations (ppm)						Mean (S)
	Control	200 SA	750 HA	1500 HA	200 SA + 750 HA	200 SA + 1500 HA	
				2018/2019 season			
Control	65.34	69.57	66.99	71.61	73.84	81.45	**71.47**
1000	54.50	60.68	60.58	64.78	68.28	73.12	**63.66**
2000	40.24	42.64	42.51	47.70	54.00	58.26	**47.56**
Mean (A)	**53.36**	**57.63**	**56.69**	**61.36**	**65.37**	**70.94**	
LSD at 5%	**For (S)= 0.51**		**For (A)= 0.86**		**For (S×A)= 1.45**		
				2019/2020 season			
Control	63.34	72.49	71.23	74.94	78.41	84.97	**74.23**
1000	53.42	65.18	64.77	68.34	70.71	74.74	**66.19**
2000	37.63	42.93	43.85	50.48	54.19	62.00	**48.51**
Mean (A)	**51.46**	**60.19**	**59.95**	**64.59**	**67.77**	**73.90**	
LSD at 5%	**For (S)= 0.42**		**For (A)= 0.56**		**For (S×A)= 0.98**		

Table 10. Effect of soil salinity (S) and foliar spray with salicylic and humic acids (A) concentrations as well as their combinations (S×A) on dry weight of herb per plant (g) of *Salvia officinalis* at 125 days after planting during 2018/2019 and 2019/2020 seasons

Soil salinity level (ppm)	Salicylic acid (SA) and humic acid (HA) concentrations (ppm)						Mean (S)
	Control	200 SA	750 HA	1500 HA	200 SA + 750 HA	200 SA + 1500 HA	
				2018/2019 season			
Control	14.46	17.13	16.55	19.34	21.14	24.04	**18.78**
1000	12.64	14.28	13.84	15.82	18.06	19.56	**15.70**
2000	7.87	9.23	9.12	10.60	13.89	15.04	**10.96**
Mean (A)	**11.66**	**13.55**	**13.17**	**15.25**	**17.70**	**19.55**	
LSD at 5%	**For (S)= 0.21**		**For (A)= 0.22**		**For (S×A)= 0.40**		
				2019/2020 season			
Control	12.86	19.32	18.91	21.17	23.15	25.54	**20.16**
1000	11.66	14.80	14.24	17.22	18.40	20.12	**16.07**
2000	6.67	9.53	10.00	12.88	13.48	16.26	**11.47**
Mean (A)	**10.40**	**14.55**	**14.38**	**17.09**	**18.34**	**20.64**	
LSD at 5%	**For (S)= 0.30**		**For (A)= 0.21**		**For (S×A)= 0.45**		

Salt Resistance Index and Total Chlorophyll Content

Effect of soil salinity level

Results under discussion in Table 11 reveal that, salt resistance index percentage of common sage significantly varied in response to soil salinity levels. However, salt resistance index percentage was significantly decreased with application of 1000 and 2000 ppm levels of soil salinity compared with control in both seasons. In other words, the decreases in this connection were about 10.93 and 10.82% for the salinity level at 1000 ppm with significant difference between this treatments and control (un-salinized plants) in the first and second seasons, respectively. However, total chlorophyll content of sage leaves was decreased compared to control in the two seasons, as a result of soil salinity treatments (Table 12). This decrease was significant in both seasons. Generally, total chlorophyll content (SPAD) was decreased as salinity level increased up to 2000 ppm. Also, the decrease in this connection was about 14.10 and 14.44% in the 1st and 2nd seasons, respectively. Also, **Nassar *et al*. (2018)** on cluster bean, **Ibrahim *et al*. (2019)** on sweet basil and **Abdelkader *et al*. (2019)** on rosemary plants came to analogous findings.

Effect of foliar spray with salicylic and humic acids concentrations

Salvia officinalis salt resistance index was significantly increased by using salicylic and humic acids concentrations compared to control in both seasons. Also, salt resistance index (%) was increased due to using of salicylic, humic and salicylic + humic acids, respectively, in most cases (Table 11). All SA and HA acids concentrations significantly increased total chlorophyll content of common sage leaves compared to control in the both seasons. Moreover, total chlorophyll content significantly increased with 200 ppm of SA + 1500 ppm of HA compared to control in the two seasons (Table 12).

These results are in harmony with those reported by **Abou El-Yazied (2011)** on *Capsicum annuum*, **Pacheco *et al*. (2013)** on *Calendula officinalis* and **Karalija and Parić (2017)** on *Ocimum basilicum* plants regarding salicylic acid effect as well as **Saadati and Baghi (2014)** on *Cicer arietinum* plant, regarding humic acid effect.

Effect of combination treatments between soil salinity and foliar spray with salicylic and humic acids concentrations

It is quite clear from the results in Tables 11 and 12 that, salt resistance index (%) of *Salvia officinalis* was increased as a result of the treatments of different acids (salicylic + humic) combined with most of salinity levels compared to un-salinized plants or those of the used salinity ones in the two seasons. Also, combination treatments between SA and HA acids and soil salinity significantly affect the common sage total chlorophyll content. Although, there was significant decrease, in this regard, due to spraying the sage plants with SA at 200 ppm + HA at 1500 ppm and were exposing to soil salinity at 0.0 and 10000 ppm. Such results hold true in the both seasons. Moreover, salicylic acid and humic acid are a well known biostimulant which has positive effects on plant growth and significantly mitigates the injuries caused by abiotic stresses (**Jafari *et al*., 2019**). Who reported that foliar by salicylic acid and ascorbic acid *via* increasing total chlorophyll content and also decreased electrolyte leakage which moderately adversed the impact of salinity stress on safflower. In connection with the photosynthetic contents of *Medicago sativa*, the humic acid showed positive influences, especially in terms of 2 and 12 dS m^{-1} salinity levels, respectively (**Sofi *et al*., 2018**).

Conclusion

From above mentioned results, it is preferable to spray common sage (*Salvia officinalis*, L.) plants with salicylic acid at 200 ppm + humic acid at 1500 ppm four times /season under moderate soil salt stress (1000 ppm) to enhance the growth parameters, yield and total chlorophyll content of salvia plants.

Table 11. Effect of soil salinity (S) and foliar spray with salicylic and humic acids (A) concentrations as well as their combinations (S×A) on salt resistance index (%) of *Salvia officinalis* plant at 125 days after planting during 2018/2019 and 2019/2020 seasons

Soil salinity level (ppm)	Salicylic acid (SA) and humic acid (HA) concentrations (ppm)						Mean (S)
	Control	200 SA	750 HA	1500 HA	200 SA +750 HA	200 SA +1500 HA	
				2018/2019 season			
Control	100.00	106.48	102.54	109.60	113.02	124.67	**109.38**
1000	83.43	92.86	92.72	99.16	104.51	111.92	**97.43**
2000	61.60	65.27	65.08	73.01	82.65	89.17	**72.79**
Mean (A)	**81.68**	**88.20**	**86.78**	**93.92**	**100.06**	**108.59**	
LSD at 5%	**For (S)= 0.88**		**For (A)= 1.31**			**For (S×A)= 2.24**	
				2019/2020 season			
Control	100.00	114.45	112.45	118.31	123.79	134.15	**117.19**
1000	84.34	102.91	102.26	107.90	111.64	117.99	**104.51**
2000	59.42	67.74	69.23	79.69	85.56	97.89	**76.59**
Mean (A)	**81.25**	**95.03**	**94.65**	**101.97**	**107.00**	**116.68**	
LSD at 5%	**For (S)= 0.67**		**For (A)= 0.87**			**For (S×A)= 1.52**	

Table 12. Effect of soil salinity (S) and foliar spray with salicylic and humic acids (A) concentrations as well as their combinations (S×A) on total chlorophyll content (SPAD) of *Salvia officinalis* plant at 88 days after planting during 2018/2019 and 2019/2020 seasons

Soil salinity level (ppm)	Salicylic acid (SA) and humic acid (HA) concentrations (ppm)						Mean (S)
	Control	200 SA	750 HA	1500 HA	200 SA + 750 HA	200 SA + 1500 HA	
				2018/2019 season			
Control	50.40	51.83	53.52	54.71	55.43	57.44	**53.89**
1000	46.75	49.25	49.12	49.57	50.58	55.23	**50.08**
2000	43.64	44.45	45.12	46.50	48.30	49.69	**46.29**
Mean (A)	**46.93**	**48.51**	**49.26**	**50.26**	**51.44**	**54.12**	
LSD at 5%	**For (S)= 0.23**		**For (A)= 0.36**			**For (S×A)= 0.61**	
				2019/2020 season			
Control	48.84	50.78	50.44	55.62	56.69	58.80	**53.53**
1000	47.08	48.10	46.92	52.22	53.17	54.77	**50.38**
2000	41.71	42.69	43.32	46.32	50.37	50.39	**45.80**
Mean (A)	**45.88**	**47.19**	**46.89**	**51.39**	**53.41**	**54.65**	
LSD at 5%	**For (S)= 0.57**		**For (A)= 0.41**			**For (S×A)= 0.86**	

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تخفيف آثار ملوحة التربة على نباتات المريمية بالرش الورقي بحامض الســـاليسيلك وحامض الهيوميك

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من أجل دراسة استجابة نباتات المريمية للرش الورقي بحامض الساليسيليك وحامض الهيوميك تحت ظروف ملوحة التربة، تم إجراء تجربتي أصص في مشتل نباتات الزينة، قسم البساتين، كلية الزراعة، جامعة الزقازيق، محافظة الشرقية، مصر خلال موسمي الشتاء المتتاليين ٢٠١٨/٢٠١٩ و ٢٠١٩/٢٠٢٠، الهدف من هذا البحث هو دراسة تأثير حمض الساليسيليك والهيوميك على تحمل نباتات المريمية للملوحة ، وكانت المعاملات كالآتي: الكنترول (الرش بالماء)، وحمض الساليسيليك بتركيز ٢٠٠ جزء في المليون، وحمض الهيوميك بتركيز ٧٥٠ جزء في المليون وكذلك ١٥٠٠ جزء في المليون، حامض الساليسيليك بتركيز ٢٠٠ جزء في المليون + حامض الهيوميك بتركيز ٧٥٠ جزء في المليون و حامض الساليسيليك بتركيز ٢٠٠ جزء في المليون + حامض الهيوميك بتركيز ١٥٠٠ جزء في المليون تحت مستويات ملوحة التربة المختلفة (صفر، ١٠٠٠ و ٢٠٠٠ جزء في المليون) وكذلك معاملات التداخل بينهما على النمو، والمساهمات المحصولية، ودليل مقاومة الملوحة والمحتوى الكلي من الكلوروفيل لنباتات المريمية، صممت التجربة كقطع منشقة مرة واحدة في ثلاث مكررات، وزعت مستويات ملوحة التربة في القطع الرئيسية ووزعت معاملات أحماض الساليسيليك والهيوميك في القطع الفرعية، ثم قياس كل من ارتفاع النبات (سم)، عدد الأفرع/نبات، الأوزان الطازجة والجافة للجذور/ النبات (جم)، طول الجذر (سم) وعدد الجذور/نبات كصفات للنمو، أيضًا الأوزان الطازجة والجافة للعشب/نبات (جم) كمساهمات محصولية وكذلك دليل مقاومة الملح ، كما تم قياس المحتوى الكلي من الكلوروفيل (وحدة سباد) في الأوراق، أوضحت النتائج أن استخدام مستويات ملوحة التربة ١٠٠٠ و ٢٠٠٠ جزء في المليون أدى إلى انخفاض ملحوظ في صفات النمو والمساهمات المحصولية والمحتوى الكلي من الكلوروفيل مقارنة بالكنترول، بالإضافة إلى ذلك، تم الحصول على أعلى القيم للصفات المذكورة أعلاه عن طريق معاملة النباتات بـ ٢٠٠ جزء في المليون من حامض الساليسيليك + ١٥٠٠ جزء في المليون من حامض الهيوميك، بشكل عام، يمكن أن يستنتج أن المعاملة بحامض الساليسيليك بتركيز ٢٠٠ جزء في المليون + ٧٥٠ أو ١٥٠٠ جزء في المليون من حامض الهيوميك، أظهرا تأثيرًا في التخفيف من تثبيط نمو المريمية وزيادة دليل مقاومة الملوحة تحت الإجهاد الملحي المتوسط (مستوى ملوحة ١٠٠٠ جزء في المليون).

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