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Alleviation of Irrigation Water Salinity Effect on *Rosmarinus officinalis* by Humic Acid

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ABSTRACT

This investigation was under taken at the farm of floriculture plants, Fac. Agric., Minia Univ. throughout the two growing seasons of 2022 and 2023 to teste the influence of humic acid at 0.0, 1000, 2000 and 4000 ppm on *Rosmarinus officinalis* growth characters, essential oil production and some chemical compositions, planted under irrigation salinity (0.0, 800, 1600 and 2400 ppm NaCl).

Data showed that all examined traits of vegetative development (plant height, branches and leaves number, stem diameter, leaf area, herb fresh and dry weights), essential oil productivity (% and yield ml/plant) and some chemical compositions (pigments content and NPK%) were decreased by increasing salinity level comparing with control during both seasons. At the same time, salinity concentrations increased both of Na% and proline content (µg/g) in dry leaves during both seasons.

Humic acid treatments significantly increased all abovementioned traits of vegetative development and volatile oil content as well as some chemical compositions except Na% and proline content (µg/g) in dry leaves during both seasons, were decreased. The best treatment was 4000 ppm humic acid in this concern.

In conclusion, treating plants with 4000 ppm humic acid can alleviate the bad effects of moderate salinity levels.

KEYWORDS: Rosemary, salinity, humic acid

1. INTRODUCTION

Rosmarinus officinalis L. a member of family Lamiaceae. The plant is an evergreen herb (Abdelkader *et al*., 2019). Rosmary is mainly consisted of di- and triterpene, phenolic compounds, and volatile oils (Aumeeruddy-Elalfi *et al*., 2015 and Aumeeruddy-Elalfi *et al*., 2016). Generally, economic value of rosemary plant due to biological activities, antitumor activity, antioxidant activity, anti-infectious activity, anti-inflammatory and analgesic activities as well as used as ornamental plant.

One of the primary biotic factors adversely influencing plant development and production globally is salt stress. Abdelkader *et al*., 2019; El-Kholy *et al*., 2020; Mehrizi *et al*., 2021; and Al-Fraihat *et al*., 2023 concluded that increasing salt level reducing rosemary plant vegetative development parameters, essential oil content and some chemical composition.

Several researchers tested the influence of humic acid at various concentrations on medical plants under salinity stress, and found positive effects on alleviating the bad effects of salinity (Mostafa, 2015 and Zulfiqar *et al*., 2019 on fennel plant; Hassan, 2019 on caraway plant; Hegazy *et al*., 2021 on sage plant; and Rekaby *et al*., 2023 on quinoa plant).

Therefore, this research aimed to evaluate the response of rosemary grown under salinity to spraying with humic acid.

2. MATERIALS AND METHODS

To assess the impact of humic acid on vegetative development parameters, volatile oil content and some chemical constituents of rosemary plant grown under salinity stress, this work was laid out at the farm of floriculture Plants, Faculty Agriculture, Minia University during 2022 and 2023 seasons.

Terminal rooted cuttings of *Rosmarinus officinalis* plant averaged 10 cm in height, 2 ml diameter and have 8 leaves were cultivated on 15th February of the two seasons of 2022 and 2023 in plastic pots (20 cm in diameter) contained 3.950 kg of sandy soil (two cutting/pot). The soil physical and chemical were analyzed according to Jackson (1973) as presented in Table 1.

Table 1. The soil physical and chemical analysis of the experimental used soil.

Soil character	Values		Soil character	Values	
	2022	2023		2022	2023
Physical properties:			**Nutrients:**		
Sand (%)	89.00	90.00	**Total N (%)**	0.01	0.01
Silt (%)	7.80	6.90	**Available P (ppm)**	2.76	2.91
Clay (%)	3.20	3.10	**Na^+ (mg/100 g soil)**	2.39	2.50
Soil type	sandy	sandy	**K^+ (mg/100 g soil)**	0.73	0.78
Chemical properties:			**DTPA-Extractable nutrients:**		
pH (1:2.5)	8.25	8.29	**Fe (ppm)**	1.06	1.12
E.C. (dS/m)	1.13	1.16	**Cu (ppm)**	0.34	0.38
O.M.	0.02	0.03	**Zn (ppm)**	0.36	0.33
$CaCO_3$	11.60	11.80	**Mn (ppm)**	0.58	0.65

The experiment used a split plot in a CRBD with replicated three times and included 16 treatments (4 x 4). There were 4 pots (8 plants) in each treatment, so the total number of used plants was 384 plants. Four irrigation water salinity treatments (0, 800, 1600 and 2400 ppm NaCl) and four humic acid (0, 1000, 2000, and 4000 ppm) were distributed among the sub-plots and the main plots, respectively. The sodium chloride was obtained from El-Gomhouria Co. For Trading Drugs, Chemicals and Medical Supplies (Al Amiriyyah, Egypt) and humic acid was released from Star Gold for Agricultural Development, Asyut District, Assiut Governorate, Egypt.

The plants were irrigated (with 500 cm^3 each/pot) two times weekly. All treatments were irrigated with tab water for two weeks (15th – 28th February), after that the plants were irrigated with salinized water beginning on March 1st and continuing until the experiment's harvest in accordance with the designated concentration. All treatments were sprayed four times with humic acid (2 times, 15th March and 1st April, before the first cut) and (2 times later, 15th June and 1st July). The plants were cut two times (1st June and 1st September) in both seasons by chopping plants at 5 cm above the soil surface.

Data were recorded for each cut: plant height (cm), stem diameter (mm), branches number, leaves area (cm^2) and number/plant, fresh and dried herb weights (g), essential oil production (percent and yield) in both cuts during both seasons, in addition to chemical constituents [content of pigments and proline, NPK and Na% in second cut only during both seasons.

The three pigment contents were colorimetrically measured as described by Fadl and Sari El-Deen (1978). Macro-elements percentages were determined according to ICARDA (2013). Proline content was measured in the second cut as described by Bates *et al*. (1973).

2.1.Statistical analysis

The acquired data were tallied and subjected to statistical analysis in accordance with MSTAT–C (1986), with an LSD test at 0.05 being employed to compare the treatment means.

3. RESULTS AND DISCUSSION

3.1. Vegetative growth indicators:

Listed data in Tables (2 to 7) indicated that irrigation water salinity treatments led to significantly increase under (800 ppm NaCl), and decreased under (1600 and 2400 ppm NaCl) for all vegetative development indicators (plant height, branches and leaves number, stem diameter, leaf area, and herb weights of fresh and dried) as facing to untreated plants (tab water) in the both cuts throughout both growing seasons. Sodium chloride at 2400 ppm produced the highest reduction comparing with control. Our results are consistent with those published by Tounekti *et al*. (2008), Kiarostami *et al*. (2010), Langroudi and Sedaghathoor (2012), Ali and Attia (2015), Abdelkader *et al*. (2019), Chetouani *et al*. (2019), El-Kholy *et al*. (2020) and Al-Fraihat *et al*. (2023) on *Rosmarinus officinalis* L.

As for humic acid application, data listed in Tables (2 to 7) showed that the three concentrations of humic acid treatments (1000, 2000 and 4000 ppm) significantly increased all abovementioned parameters relative to untreated plants for both cuts during first and second seasons. In all cases, at 4000 ppm, humic acid outperformed other treatments in terms of effectiveness in enhancing abovementioned vegetative growth parameters.

Similar outcomes to ours were achieved by Sharaf El Din *et al*. (2013), Fazli and Abbaszadeh (2015), Jalayerinia *et al*. (2017), and Zghair *et al*. (2022) on rosemary; El-Khateeb *et al*. (2017) and Hammam *et al*. (2019) on marjoram; Dehsorkhi *et al*. (2018) on cumin;

Table 2. Response of plant height, stem diameter and branches number of *Rosmarinus officinalis* to salinity and humic acid treatments in both cuts throughout the first season.

Humic acid treatments (ppm)	Irrigation water salinity (ppm) (A)									
	0.0	800	1600	2400	Mean (B)	0.0	800	1600	2400	Mean (B)
	The first cut					The second cut				
	Plant height (cm)									
Control	26.5	27.8	22.6	19.6	24.1	26.5	27.8	22.6	19.5	24.1
Humic acid 1000	27.8	29.2	23.7	20.6	25.3	28.0	29.5	23.8	20.8	25.5
Humic acid 2000	28.7	30.1	25.8	21.6	26.6	29.2	30.6	26.3	21.9	27.0
Humic acid 4000	29.2	32.1	26.3	22.0	27.4	30.0	33.0	27.0	22.6	28.2
Mean (A)	28.1	29.8	24.6	20.9	25.9	28.4	30.2	24.9	21.2	26.2
L.S.D. at 5 %	A: 1.6		B: 1.1		AB: 2.2	A: 1.7		B: 1.3		AB: 2.6
	Stem diameter (mm)									
Control	4.0	4.3	3.7	3.3	3.8	4.2	4.5	3.9	3.5	4.0
Humic acid 1000	4.1	4.4	3.8	3.4	3.9	4.3	4.6	4.0	3.6	4.1
Humic acid 2000	4.2	4.5	3.9	3.5	4.0	4.5	4.8	4.1	3.7	4.3
Humic acid 4000	4.3	4.6	4.1	3.7	4.2	4.6	4.9	4.3	3.9	4.4
Mean (A)	4.2	4.5	3.9	3.5	4.0	4.4	4.7	4.1	3.7	4.2
L.S.D. at 5 %	A: 0.3		B: 0.1		AB: 0.2	A: 0.2		B: 0.1		AB: 0.2
	Branches number									
Control	3.01	3.19	2.41	2.16	2.69	3.16	3.38	2.55	2.31	2.85
Humic acid 1000	3.15	3.35	2.52	2.27	2.82	3.31	3.55	2.67	2.43	2.99
Humic acid 2000	3.31	3.52	2.65	2.39	2.97	3.48	3.73	2.81	2.56	3.14
Humic acid 4000	3.47	3.69	2.78	2.51	3.11	3.64	3.91	2.95	2.69	3.30
Mean (A)	3.24	3.44	2.59	2.33	2.90	3.40	3.64	2.75	2.50	3.07
L.S.D. at 5 %	A: 0.19		B: 0.13		AB: 0.26	A: 0.23		B: 0.12		AB: 0.24

Fahmy and Hassan (2019) on roselle plant; Faizy (2019) on black cumin; Mohammed et al. (2019) on chamomile; Omer et al. (2020) on caraway; and Tawfik (2022) on fennel.

The effect between the combination of salinized water and humic acid was significant for abovementioned vegetative growth parameters in both cuts during the first and second seasons. Generally, the interaction treatment of water salinity at 800 ppm in combination with humic acid at 4000 ppm produced the highest values. Similarly, Mostafa (2015) and Zulfiqar *et al*. (2019) on fennel; Hegazy *et al*. (2020) on sage; and Rekaby *et al*. (2023) on quinoa.

3.2. Essential oil productivity:

3.2.1. Essential oil (%):

According to Tables 6 and 7, the proportion of essential oil in the rosemary herb increased considerably in both cuttings over both seasons when it was exposed to the control (tab water) due to the water salinity stress (800 and 1600 ppm NaCl). At the same time, the oil percentage significantly decreased under 2400 ppm NaCl in the first and second cuts throughout both growing seasons comparing with the control. The influence of saline water on volatile oil (%) was emphasized by Tounekti *et al*. (2008), Ali and Attia (2015), Abdelkader *et al*. (2019), Sarmoum *et al*. (2019), and El-Kholy *et al*. (2020) on *Rosmarinus officinalis*, who concluded that volatile oil (%) was reduced considerably with rising salinity concentration. On contrast, Bidgoli *et al*. (2019) and Al-Fraihat *et al*. (2023) on *Rosmarinus officinalis*, mentioned that essential oil (%) was improved under moderate salinity compared with the control.

Regarding the effect of humic acid, data presented in Tables (6 and 7) mentioned that all humic acid (1000, 2000 and 4000 ppm) considerably increased essential oil (%) in comparison with control.

Table 3. Response of plant height, stem diameter and branches number of *Rosmarinus officinalis* to salinity and humic acid treatments in both cuts throughout the second season.

Humic acid treatments (ppm)	Irrigation water salinity (ppm) (A)									
	0.0	800	1600	2400	Mean (B)	0.0	800	1600	2400	Mean (B)
	The first cut					The second cut				
Plant height (cm)										
Control	30.5	32.0	26.0	22.5	27.8	30.8	32.3	26.3	22.7	28.0
Humic acid 1000	32.0	33.6	27.2	23.7	29.1	32.6	34.3	27.7	24.2	29.7
Humic acid 2000	33.0	34.6	29.7	24.8	30.5	34.0	35.6	30.6	25.5	31.4
Humic acid 4000	33.6	36.9	30.2	25.3	31.5	34.9	38.4	31.4	26.3	32.8
Mean (A)	32.3	34.3	28.3	24.1	29.7	33.1	35.2	29.0	24.7	30.5
L.S.D. at 5 %	A: 2.0		B: 1.3		AB: 2.6	A: 1.9		B: 1.2		AB: 2.4
Stem diameter (mm)										
Control	4.1	4.4	3.8	3.4	4.0	4.3	4.6	4.1	3.7	4.2
Humic acid 1000	4.2	4.5	4.0	3.5	4.1	4.4	4.7	4.2	3.8	4.3
Humic acid 2000	4.3	4.6	4.1	3.6	4.2	4.6	4.9	4.3	3.9	4.4
Humic acid 4000	4.4	4.7	4.3	3.8	4.3	4.7	5.0	4.5	4.1	4.6
Mean (A)	4.3	4.6	4.0	3.6	4.1	4.5	4.8	4.3	3.9	4.4
L.S.D. at 5 %	A: 0.2		B: 0.1		AB: 0.2	A: 0.3		B: 0.1		AB: 0.2
Branches number										
Control	3.04	3.22	2.43	2.18	2.72	3.35	3.58	2.70	2.45	3.02
Humic acid 1000	3.21	3.42	2.57	2.32	2.88	3.54	3.80	2.86	2.60	3.20
Humic acid 2000	3.41	3.63	2.73	2.46	3.06	3.76	4.03	3.03	2.76	3.40
Humic acid 4000	3.61	3.84	2.89	2.61	3.24	3.97	4.26	3.22	2.93	3.59
Mean (A)	3.32	3.53	2.66	2.39	2.97	3.65	3.92	2.95	2.69	3.30
L.S.D. at 5 %	A: 0.20		B: 0.16		AB: 0.32	A: 0.26		B: 0.18		AB: 0.36

Table 4. Response of leaves number, leaf area and herb fresh weight of *Rosmarinus officinalis* to salinity and humic acid treatments in both cuts throughout the first season.

Humic acid treatments (ppm)	Irrigation water salinity (ppm) (A)									
	0.0	800	1600	2400	Mean (B)	0.0	800	1600	2400	Mean (B)
	The first cut					The second cut				
	Leaves number									
Control	138.47	145.28	118.04	102.15	125.99	139.83	146.64	119.40	103.06	127.23
Humic acid 1000	145.31	152.58	123.52	107.62	132.26	148.04	155.76	125.79	109.89	134.87
Humic acid 2000	149.89	157.15	134.90	112.64	138.64	154.43	161.70	138.99	115.82	142.73
Humic acid 4000	152.64	167.64	137.20	114.94	143.10	158.55	174.45	142.65	119.48	148.78
Mean (A)	146.58	155.66	128.41	109.34	135.00	150.21	159.64	131.71	112.06	138.40
L.S.D. at 5 %	A: 8.08		B: 6.25		AB: 12.50	A: 9.41		B: 7.60		AB: 15.20
	Leaf area (cm^2)									
Control	0.36	0.39	0.33	0.30	0.35	0.36	0.39	0.33	0.30	0.35
Humic acid 1000	0.38	0.41	0.34	0.32	0.36	0.39	0.42	0.35	0.33	0.37
Humic acid 2000	0.44	0.48	0.42	0.37	0.43	0.45	0.49	0.43	0.38	0.44
Humic acid 4000	0.50	0.54	0.48	0.40	0.48	0.52	0.56	0.50	0.42	0.50
Mean (A)	0.42	0.46	0.39	0.35	0.40	0.43	0.47	0.40	0.36	0.41
L.S.D. at 5 %	A: 0.02		B: 0.1		AB: 0.02	A: 0.03		B: 0.02		AB: 0.04
	Herb fresh weight/plant (g)									
Control	11.90	12.48	10.14	8.78	10.82	12.01	12.60	10.26	8.85	10.93
Humic acid 1000	12.51	13.14	10.64	9.27	11.39	12.75	13.41	10.83	9.46	11.61
Humic acid 2000	12.94	13.56	11.64	9.72	11.97	13.33	13.96	12.00	10.00	12.32
Humic acid 4000	13.20	14.50	11.87	9.94	12.38	13.72	15.09	12.34	10.34	12.87
Mean (A)	12.64	13.42	11.07	9.43	11.64	12.95	13.76	11.36	9.66	11.93
L.S.D. at 5 %	A: 0.77		B: 0.56		AB: 1.12	A: 0.80		B: 0.67		AB: 1.34

Table 5. Response of leaves number, leaf area and herb fresh weight/plant of *Rosmarinus officinalis* to salinity and humic acid treatments in both cuts throughout the second season.

Humic acid treatments (ppm)	Irrigation water salinity (ppm) (A)									
	0.0	800	1600	2400	Mean (B)	0.0	800	1600	2400	Mean (B)
	The first cut					The second cut				
	Leaves number									
Control	120.31	126.21	102.60	88.98	109.53	120.31	126.21	102.60	88.53	109.41
Humic acid 1000	126.24	132.60	107.62	93.54	115.00	127.15	133.96	108.08	94.45	115.91
Humic acid 2000	130.36	136.71	117.18	98.11	120.59	132.63	138.99	119.45	99.47	122.63
Humic acid 4000	132.66	145.83	119.48	99.95	124.48	136.29	149.92	122.66	102.67	127.89
Mean (A)	127.39	135.34	111.72	95.15	117.40	129.09	137.27	113.20	96.28	118.96
L.S.D. at 5 %	A: 7.91	B: 4.47		AB: 8.94		A: 8.16	B: 6.50		AB: 13.00	
	Leaf area (cm^2)									
Control	0.37	0.40	0.34	0.31	0.35	0.37	0.40	0.35	0.32	0.36
Humic acid 1000	0.39	0.42	0.35	0.33	0.37	0.39	0.42	0.36	0.34	0.38
Humic acid 2000	0.45	0.49	0.43	0.38	0.44	0.45	0.49	0.44	0.39	0.44
Humic acid 4000	0.51	0.55	0.49	0.41	0.49	0.52	0.56	0.50	0.42	0.50
Mean (A)	0.43	0.46	0.40	0.35	0.41	0.43	0.47	0.41	0.36	0.42
L.S.D. at 5 %	A: 0.03	B: 0.02		AB: 0.04		A: 0.04	B: 0.02		AB: 0.04	
	Herb fresh weight/plant (g)									
Control	10.34	10.84	8.81	7.64	9.41	10.34	10.84	8.81	7.61	9.40
Humic acid 1000	10.87	11.42	9.27	8.05	9.90	10.95	11.53	9.31	8.13	9.98
Humic acid 2000	11.25	11.80	10.11	8.47	10.41	11.45	12.00	10.31	8.58	10.58
Humic acid 4000	11.48	12.62	10.34	8.65	10.77	11.79	12.97	10.61	8.88	11.06
Mean (A)	10.98	11.67	9.63	8.20	10.12	11.13	11.84	9.76	8.30	10.26
L.S.D. at 5 %	A: 0.68	B: 0.49		AB: 0.98		A: 0.71	B: 0.58		AB: 1.16	

Table 6. Response of herb dried weight/plant, essential oil percentage and oil yield of *Rosmarinus officinalis* to salinity and humic acid treatments in both two cuts throughout the first season.

Humic acid treatments (ppm)	Irrigation water salinity (ppm) (A)									
	0.0	800	1600	2400	Mean (B)	0.0	800	1600	2400	Mean (B)
	The first cut					The second cut				
Herb dried weight/plant (g)										
Control	6.55	6.86	5.58	4.83	5.95	6.61	6.93	5.64	4.87	6.01
Humic acid 1000	6.89	7.24	5.86	5.11	6.28	7.03	7.39	5.97	5.21	6.40
Humic acid 2000	7.14	7.49	6.43	5.37	6.60	7.36	7.71	6.62	5.52	6.80
Humic acid 4000	7.30	8.02	6.56	5.50	6.84	7.59	8.34	6.82	5.72	7.12
Mean (A)	6.97	7.40	6.11	5.20	6.42	7.14	7.59	6.26	5.33	6.58
L.S.D. at 5 %	A: 0.41		B: 0.30		AB: 0.60	A: 0.43		B: 0.38		AB: 0.76
Essential oil (%)										
Control	1.03	1.17	1.19	0.90	1.07	1.04	1.18	1.20	0.91	1.08
Humic acid 1000	1.08	1.22	1.23	1.02	1.14	1.10	1.24	1.25	1.04	1.16
Humic acid 2000	1.14	1.28	1.30	1.11	1.21	1.16	1.31	1.33	1.13	1.23
Humic acid 4000	1.19	1.35	1.37	1.13	1.26	1.23	1.39	1.41	1.16	1.30
Mean (A)	1.11	1.26	1.27	1.04	1.17	1.13	1.28	1.30	1.06	1.19
L.S.D. at 5 %	A: 0.06		B: 0.05		AB: 0.10	A: 0.07		B: 0.04		AB: 0.08
Essential oil yield (ml/plant)										
Control	0.059	0.070	0.058	0.038	0.056	0.069	0.082	0.068	0.044	0.066
Humic acid 1000	0.065	0.077	0.063	0.045	0.062	0.077	0.092	0.075	0.054	0.074
Humic acid 2000	0.071	0.083	0.073	0.052	0.070	0.085	0.101	0.088	0.062	0.084
Humic acid 4000	0.076	0.094	0.078	0.054	0.076	0.093	0.116	0.096	0.066	0.093
Mean (A)	0.067	0.081	0.068	0.047	0.066	0.081	0.098	0.082	0.057	0.079
L.S.D. at 5 %	A: 0.015		B: 0.007		AB: 0.014	A: 0.016		B: 0.008		AB: 0.016

Table 7. Response of herb dried weight/plant, essential oil percentage and oil yield of *Rosmarinus officinalis* to salinity and humic acid treatments in both cuts throughout the second season.

Humic acid treatments (ppm)	Irrigation water salinity (ppm) (A)									
	0.0	800	1600	2400	Mean (B)	0.0	800	1600	2400	Mean (B)
	The first cut					The second cut				
	Herb dried weight/plant (g)									
Control	5.69	5.96	4.85	4.20	**5.17**	5.69	5.96	4.85	4.19	**5.17**
Humic acid 1000	5.99	6.29	5.11	4.44	5.46	6.03	6.35	5.13	4.48	5.50
Humic acid 2000	6.21	6.51	5.58	4.68	5.74	6.32	6.62	5.69	4.74	5.84
Humic acid 4000	6.35	6.98	5.72	4.78	5.96	6.52	7.17	5.87	4.91	6.12
Mean (A)	6.06	6.44	5.31	4.52	5.58	6.14	6.53	5.38	4.58	5.66
L.S.D. at 5 %	A: 0.37		B: 0.28		AB: 0.56	A: 0.39		B: 0.31		AB: 0.62
	Essential oil percentage (%)									
Control	1.05	1.19	1.21	0.92	1.09	1.06	1.20	1.22	0.93	1.10
Humic acid 1000	1.11	1.26	1.27	1.05	1.17	1.14	1.29	1.30	1.08	1.20
Humic acid 2000	1.19	1.33	1.35	1.15	1.26	1.22	1.38	1.40	1.19	1.29
Humic acid 4000	1.25	1.42	1.44	1.19	1.32	1.30	1.47	1.49	1.23	1.38
Mean (A)	1.15	1.30	1.32	1.08	1.21	1.18	1.34	1.35	1.11	1.24
L.S.D. at 5 %	A: 0.07		B: 0.05		AB: 0.10	A: 0.06		B: 0.04		AB: 0.08
	Essential oil yield (ml/plant)									
Control	0.060	0.071	0.059	0.039	0.057	0.060	0.072	0.059	0.039	0.057
Humic acid 1000	0.066	0.079	0.065	0.047	0.064	0.069	0.082	0.067	0.048	0.066
Humic acid 2000	0.074	0.087	0.075	0.054	0.072	0.077	0.091	0.080	0.056	0.076
Humic acid 4000	0.079	0.099	0.082	0.057	0.079	0.085	0.105	0.087	0.060	0.085
Mean (A)	0.069	0.084	0.070	0.049	0.068	0.072	0.088	0.073	0.051	0.071
L.S.D. at 5 %	A: 0.012		B: 0.006		AB: 0.012	A: 0.015		B: 0.007		AB: 0.014

In general, throughout the first and second seasons in both cuts, the essential oil percentage was gradually elevated with increasing humic acid level. So, humic acid at 4000 ppm produced the highest rise in this regard.

The humic acid treatments positively enhanced essential oil percentage as emphasized by Sharaf El Din *et al*. (2013), Jalayerinia *et al*. (2017), and Zghair *et al*. (2022) on rosemary plants.

The interaction between main and sub-plots was significant regarding essential oil percentage in all cases. Watered plants with 800 or 1600 ppm NaCl and in combination with 4000 ppm humic acid resulted the highest percentages in all cases; or sprayed with humic acid at 2000 ppm in some cases.

Humic acid help to alleviated bad effects of saline water as reported by Mostafa (2015) and Zulfiqar *et al*. (2019) on fennel plant; Hanfy *et al*. (2019), on oregano; Hassan (2019) on caraway plants; Hegazy *et al*. (2020 and 2021) on sage; and Rekaby *et al*. (2023) on quinoa plant.

3.2.2. Essential oil yield (ml/plant):

Regarding the effect of water salinity stress, data displayed in Tables (6 and 7) proved that the essential oil yield in the studied plant significantly improved in both cuts throughout both seasons facing control (tab water) for 800 ppm NaCl. While, under 1600 ppm NaCl, it was slightly increased, moreover, 2400 ppm NaCl significantly decreased essential oil yield facing the control.

The harmful effect of high levels of saline water on essential oil yield was emphasized by Tounekti *et al*. (2008), Ali and Attia (2015), Abdelkader *et al*. (2019), Sarmoum *et al*. (2019), and El-Kholy *et al*. (2020) on *Rosmarinus officinalis*.

Concerning the humic acid treatments, Tables (6 and 7) pointed out that the used concentrations of humic acid (1000, 2000 and 4000 ppm) significantly increased essential oil yield over the control. Humic acid at 4000 ppm recorded the highest values, followed by 2000 ppm without significant differences between 4000 and 2000 ppm treatments in the first season only.

The use of humic acid improved the output of essential oils as proved by Sharaf El Din *et al*. (2013), Jalayerinia *et al*. (2017), and Zghair *et al*. (2022) on rosemary plants.

The combination between main and sub-plots was significant for yield of essential oil in double cuts during both seasons. The highest oil yields were recorded from plants watered with 800 NaCl and treated with 2000 or 4000 ppm humic acid in all cases.

Humic acid help to alleviated bad effects of saline water as reported by Hassan (2019) on caraway plants; Hegazy *et al*. (2020 and 2021) on sage; and Rekaby *et al*. (2023) on quinoa plant.

3.3. Chemical composition:

3.3.1. Chlorophylls, carotenoids content and NPK%

Tables 8 and 9 displayed that significant improvement chlorophyll a, chlorophyll b, carotenoids, and NPK% were found with water salinity at 800 ppm NaCl in 2nd cutting in throughout two seasons facing untreated plants. On the other hand, irrigated plants at 1600 and 2400 ppm NaCl significantly reduced the abovementioned parameters in 2nd cutting in throughout two seasons facing untreated plats.

The deleterious effects of salinity stress on photosynthetic pigments and NPK% were mentioned by Kiarostami *et al*. (2010), Tounekti *et al*. (2011), Langroudi and Sedaghathoor (2012), Abdelkader *et al*. (2019), Chetouani *et al*. (2019), and El-Kholy *et al*. (2020) on rosemary.

Regarding the influence of humic acid (1000, 2000 and 4000 ppm), data showed that all three tested pigments contents and NPK% were significantly increased in 2nd cut during couple seasons as presented in Tables (8 and 9). Humic acid at 4000 ppm resulted the best contents overall.

Similarly, El-Khateeb *et al*. (2017) on marjoram; Mohammadi *et al*. (2018) on cumin plants; Fahmy and Hassan (2019) on roselle plant; Faizy (2019) on *Nigella sativa*; and Omer *et al*. (2020) on *Carum carvi* plants.

The effect of interaction treatments was significant for pigments content and NPK% in the 2nd cut during couple seasons (Tables 8 and 9). The greatest numbers (in all cases) were

Table 8. Response of chlorophyll a, b and carotenoids of *Rosmarinus officinalis* to salinity and humic acid treatments in the second cuts throughout both seasons.

Humic acid treatments (ppm)	Irrigation water salinity (ppm) (A)									
	0.0	800	1600	2400	Mean (B)	0.0	800	1600	2400	Mean (B)
	The first cut					The second cut				
	Chlorophyll a (mg/g f.w.)									
Control	3.131	3.289	3.124	2.967	3.128	3.232	3.394	3.224	3.063	3.228
Humic acid 1000	3.350	3.517	3.183	3.156	3.301	3.457	3.630	3.285	3.258	3.408
Humic acid 2000	3.517	3.728	3.355	3.188	3.447	3.630	3.848	3.463	3.290	3.558
Humic acid 4000	3.693	3.878	3.490	3.316	3.594	3.849	4.041	3.638	3.456	3.746
Mean (A)	3.414	3.593	3.279	3.149	3.359	3.542	3.728	3.402	3.267	3.485
L.S.D. at 5 %	A: 0.105		B: 0.070		AB: 0.140	A: 0.115		B: 0.095		AB: 0.190
	Chlorophyll b (mg/g f.w.)									
Control	1.040	1.096	1.041	0.989	1.042	1.074	1.131	1.075	1.021	1.075
Humic acid 1000	1.116	1.173	1.059	1.007	1.089	1.152	1.210	1.094	1.039	1.124
Humic acid 2000	1.173	1.230	1.107	1.051	1.140	1.210	1.269	1.143	1.085	1.177
Humic acid 4000	1.231	1.292	1.163	1.105	1.198	1.283	1.347	1.212	1.151	1.248
Mean (A)	1.137	1.195	1.090	1.035	1.114	1.180	1.239	1.131	1.074	1.156
L.S.D. at 5 %	A: 0.038		B: 0.030		AB: 0.060	A: 0.055		B: 0.035		AB: 0.070
	Carotenoids (mg/g f.w.)									
Control	1.033	1.116	1.062	1.009	1.055	1.046	1.129	1.074	1.021	1.067
Humic acid 1000	1.136	1.192	1.080	1.025	1.108	1.150	1.206	1.093	1.037	1.121
Humic acid 2000	1.193	1.250	1.127	1.072	1.160	1.207	1.265	1.141	1.084	1.174
Humic acid 4000	1.252	1.313	1.183	1.125	1.218	1.266	1.328	1.197	1.138	1.232
Mean (A)	1.150	1.215	1.110	1.055	1.132	1.167	1.232	1.126	1.070	1.149
L.S.D. at 5 %	A: 0.035		B: 0.030		AB: 0.060	A: 0.038		B: 0.030		AB: 0.060

Table 9. Response of nitrogen, phosphorus and potassium percentage in dry leaves of *Rosmarinus officinalis* to salinity and humic acid treatments in the second cut throughout both seasons.

Humic acid treatments (ppm)	Irrigation water salinity (ppm) (A)									
	0.0	800	1600	2400	Mean (B)	0.0	800	1600	2400	Mean (B)
	The first season					The second season				
					Nitrogen (%)					
Control	2.397	2.520	2.253	2.141	2.328	2.426	2.550	2.280	2.167	2.356
Humic acid 1000	2.517	2.643	2.366	2.248	2.444	2.572	2.701	2.418	2.297	2.497
Humic acid 2000	2.668	2.801	2.508	2.383	2.590	2.753	2.891	2.588	2.459	2.673
Humic acid 4000	2.855	3.000	2.684	2.550	2.772	2.975	3.126	2.797	2.657	2.889
Mean (A)	2.609	2.741	2.453	2.331	2.533	2.635	2.768	2.477	2.354	2.559
L.S.D. at 5 %	A: 0.130		B: 0.094		AB: 0.188	A: 0.142		B: 0.115		AB: 0.230
					Phosphorus (%)					
Control	0.249	0.264	0.235	0.212	0.240	0.251	0.267	0.237	0.214	0.242
Humic acid 1000	0.261	0.277	0.245	0.221	0.251	0.264	0.280	0.248	0.224	0.254
Humic acid 2000	0.274	0.290	0.258	0.232	0.264	0.279	0.296	0.263	0.237	0.269
Humic acid 4000	0.288	0.305	0.270	0.243	0.277	0.297	0.315	0.279	0.251	0.285
Mean (A)	0.268	0.284	0.252	0.227	0.258	0.271	0.287	0.255	0.229	0.260
L.S.D. at 5 %	A: 0.008		B: 0.006		AB: 0.012	A: 0.009		B: 0.008		AB: 0.016
					Potassium (%)					
Control	2.311	2.450	2.172	2.042	2.244	2.334	2.482	2.205	2.087	2.277
Humic acid 1000	2.427	2.573	2.316	2.177	2.373	2.451	2.606	2.351	2.225	2.408
Humic acid 2000	2.549	2.702	2.432	2.286	2.492	2.574	2.737	2.468	2.336	2.529
Humic acid 4000	2.676	2.837	2.553	2.401	2.617	2.730	2.874	2.591	2.454	2.662
Mean (A)	2.491	2.641	2.368	2.227	2.432	2.516	2.667	2.392	2.249	2.456
L.S.D. at 5 %	A: 0.102		B: 0.015		AB: 0.030	A: 0.110		B: 0.017		AB: 0.034

achieved by the interaction treatment of 800 ppm NaCl with 4000 ppm humic acid.

Close findings were obtained by Sofi *et al*. (2018) on *Medicago sativa*; Hassan (2019) on caraway; and Hegazy *et al*. (2021) on sage.

3.3.2. Sodium (%) and proline content (µg/g):

Opposite trend to previous chemical constituents, data presented in Table (10) mentioned that irrigation water salinity (800, 1600 and 2400 ppm NaCl) significantly increased both sodium (%) and proline content (µg/g) in both seasons facing the control.
Similar results were reported by Langroudi and Sedaghathoor (2012), Ali and Attia (2015), Chetouani *et al*. (2019) Al-Fraihat *et al*. (2023) on *Rosmarinus officinalis*.

Humic acid treatments had positive effect on reducing Na percentage and proline content facing the control in couple seasons (Table 10). It is observed that the treatment of high level of humic acid (4000 ppm) was more effective than either 2000 or 1000 ppm in both seasons, respectively.

The interaction effect between salinized water and humic acid was significant for Na (%) and proline (µg/g) in couple seasons. The greatest numbers of Na and proline were obtained from plants watered by 2400 ppm NaCl without any spray of humic acid in both seasons. Contrarily, the lowest values of both characters were detected with control plants sprayed with 4000 ppm humic acid.

Many authors stated that salt stress increased Na concentration and proline content and found that humic acid alleviate the bad effects under salinity, such as Zulfiqar *et al*. (2019) on fennel plant; Hassan (2019) on caraway plants; and Hegazy *et al*. (2021) on sage plant.

4. DISCUSSION

Humic acid's function as an enhancer on vegetative development, productivity and some chemical constituents under water salinity stress because humic acid contains antioxidant which may be improved salt tolerance by prevent ROS (reactive oxygen species) from damaging cellular components (Alscher *et al*., 2002). According to Samavat and Malakuti (2006), humic acid is an organic substance that is considered ecologically acceptable and has low quantities of chemicals that are similar to hormones. It may be used to improve agricultural productivity.

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Table 10. Response of sodium percentage and proline content in dry leaves of *Rosmarinus officinalis* to salinity and humic acid treatments in the second cut throughout both seasons.

Humic acid treatments (ppm)	Irrigation water salinity (ppm) (A)									
	0.0	800	1600	2400	Mean (B)	0.0	800	1600	2400	Mean (B)
	The first season					The second season				
Sodium (%)										
Control	1.881	1.994	2.134	2.326	2.084	1.900	2.014	2.155	2.349	2.105
Humic acid 1000	1.787	1.874	2.006	2.186	1.963	1.808	1.896	2.030	2.212	1.987
Humic acid 2000	1.680	1.780	1.906	2.077	1.861	1.704	1.805	1.933	2.106	1.887
Humic acid 4000	1.613	1.709	1.830	1.994	1.787	1.648	1.747	1.870	2.038	1.826
Mean (A)	1.740	1.839	1.969	2.146	1.924	1.758	1.858	1.989	2.167	1.943
L.S.D. at 5 %	A: 0.095	B: 0.040	AB: 0.080			A: 0.098	B: 0.023	AB: 0.046		
Proline content (µg/g)										
Control	258	274	289	315	284	261	277	292	318	287
Humic acid 1000	243	259	272	296	268	248	264	277	302	273
Humic acid 2000	228	245	255	278	252	235	252	263	286	259
Humic acid 4000	210	225	231	240	227	218	234	240	250	236
Mean (A)	235	251	262	282	257	237	253	264	285	260
L.S.D. at 5 %	A: 11	B: 7	AB: 14			A: 13	B: 9	AB: 18		

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الملخص العربي

تخفيف تأثير ملوحة ماء الري علي الحصالبان باستخدام حمض الهيوميك

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قسم البساتين، كلية الزراعة، جامعة المنيا

أُجريت هذه التجربة بمزرعة نباتات الزينة، قسم البساتين، كلية الزراعة، جامعة المنيا، خلال موسمي نمو متعاقبين ٢٠٢٢ و ٢٠٢٣، لتقييم تأثير حمض الهيوميك بتركيز ١٠٠٠ و ٢٠٠٠ و ٤٠٠٠ جزء في المليون، علي صفات النمو وإنتاجية الزيت وبعض المكونات الكيماوية لنبات الحصالبان النامي تحت إجهاد ملوحة ماء الري (٠,٠ و ٨٠٠ و ١٦٠٠ و ٢٤٠٠ جزء في المليون كلوريد صوديوم).
أظهرت النتائج أن جميع صفات النمو الخضري المدروسة (ارتفاع النبات، عدد الفروع والأوراق، قطر الساق، مساحة الورقة، والأوزان الطازجة والجافة للعشب) وإنتاجية الزيت الطيار (النسبة المئوية ومحصول الزيت مل/النبات) وكذلك بعض المكونات الكيميائية (محتوي الصبغات وNPK%) قد انخفضت بزيادة مستوي الملوحة مقارنة مع معاملة الكنترول، في نفس الوقت، قد أدت الملوحة إلي زيادة النسبة المئوية للصوديوم ومحتوي البرولين (ملجم/جم) في الأوراق الجافة خلال موسمي النمو.
زادت زيادة معنوية جميع صفات النمو الخضري ومحتوي الزيت الطيار بالإضافة إلى بعض المكونات الكيميائية المذكورة أعلاه، بإستثناء النسبة المئوية للصوديوم ومحتوي البرولين (ملليجم/جم) في الأوراق الجافة خلال موسمي النمو، فقد انخفضت، نتيجة معاملات حمض الهيوميك. وكانت معاملة الهيوميك بتركيز ٤٠٠٠ جزء في المليون هي الأفضل في هذا الشأن.
يمكن القول، أن رش النباتات بحمض الهيوميك بتركيز ٤٠٠٠ جزء في المليون يمكن أن يؤدي إلي تخفيف التأثيرات السلبية للمستويات المتوسطة من الملوحة.

الكلمات المفتاحية: الحصالبان – الملوحة – حمض الهيوميك.