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Effect of salinity, seaweed extract and salicylic acid on growth, essential oil and chemical composition of *plectranthus amboinicus* (lour) Spreng plant.

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This investigation was carried out at Faculty of Agriculture, Cairo University and the Experimental Farm of Medicinal and Aromatic Plant Research Department, Horticulture Research Institute, Agricultural Research Center, Dokki, Giza, during two successive seasons of 2015 and 2016.This work was designed to investigate the effect of salinity (control, 1500 and 3000 ppm), seaweed extract at the rates of (250, 500 and 1000 ppm) and salicylic acid at the rates of (150, 300 and 450ppm) on vegetative growth and chemical composition of *Plectranthus amboinicus* (Lour) Spreng plant. The results indicated that salinity decreased fresh, dry weight, essential oil yield/plant. Also, N, P, K and total carbohydrates contents in plant parts were greatly reduced under saline water. Essential oil %, Ƥ- cymene, β-caryophyllene and α-humulene contents in the essential oil, sodium and proline contents were increased with increasing salinity concentrations. However, using the seaweed extracts and salicylic acid significantly increased all the studied characters. Salicylic acid was superior in its significant effect. Foliar application of salicylic acid reduced prominently the hazard effects of salinity and improved all the previous characters under salinity treatments.

Keywords: Salinity, Seaweed Extract, Salicylic Acid, Essential Oil, *Plectranthus amboinicus*.

INTRODUCTION

Plectranthus amboinicus (Lour.) Spreng. is a semi-succulent perennial plant belongs the family Lamiaceae with a pungent oregano-like flavor and odor. It is native to Southern and Eastern Africa. It is widely cultivated and naturalized elsewhere in the tropics, where it is used as a medicine, spice and ornamental plant. It can reach over 1 m in height, the stem is fleshy,(Steenis and Steenis-Kruseman, 1950). *Plectranthus amboinicus* is attributed to have antiseptic, antimicrobial, appetizing, digestive, carminative, stomachic, anthelmintic, binding, deodorant, diuretic and tonic properties. It is commonly used in respiratory tract disorders as a bronchodilator, antitussive, and expectorant (Lopes et al., 2017).The antiseptic and antimicrobial properties of the plant have been attributed to the presence of compounds such as carvacrol, thymol, flavones, phenols, tannins and aromatic acids (DeFilipps et al., 2004).

Salinity is a major limiting factor in agricultural production and exerts unfavorable influence on various physiological and biochemical processes associated with plant growth and development (Pitman and Lauchli, 2002). One of the primary effects of increasing the salinity in growth medium is the inhibition of K^+, Ca_2^+ and NO^-_3 ion uptake by plant roots. Salt stress limits agricultural production throughout the world and is becoming an increasingly global problem that affects approximately 20 percent of global irrigated land.

Salt environment lead to cellular dehydration, which causes osmotic stress and exosmosis of cytoplasm resulting in a reduction of the cytosolic and vacuolar volumes. Salt stress often creates both ionic as well as osmotic stress in plants, resulting in accumulation or decrease of specific secondary metabolites in plants (Pradhan et al., 2017).

Application of seaweed extract improves plant's ability to tolerate environmental stresses and reduces insects' attacks. Seaweeds are broadly used in industry, agriculture, medicine, and nutrition and novel technologies have been developed to make use of this potential source (Partani, 2013).

Salicylic acid has been used by humans because of its therapeutic properties. Salicylic acid, chemically known as 2-hydroxy benzoic acid is one of a diverse group of phenolic compounds, consisting of an aromatic ring bearing a hydroxyl group or its functional derivative, which is synthesized by plants. Salicylic acid biosynthetic pathway in plants has two distinct pathways, the isochorismate (IC) pathway and the phenylalanine ammonialyase (PAL) pathway. Moreover, salicylic acid plays exclusive role in plant growth, thermo genesis, flower induction and uptake of ions. It affects ethylene biosynthesis, stomatal movement and also reverses the effects of ABA on leaf abscission (Yusuf et al., 2013).

Therefore, the aim of this study was to evaluate the adverse effects of irrigation water salinity on *Plectrunthus amboinicus* (Lour) Spreng plants, and to investigate the possibility of using seaweed extract and salicylic acid to overcome these effects under the local condition in Egypt.

MATERIALS AND METHODS

This investigation was carried out at Faculty of Agriculture, Cairo University and the Experimental Farm of Medicinal and Aromatic Plant Research Department, Horticulture Research Institute, Agricultural Research Center, Dokki, Giza, during two successive seasons of 2015 and 2016to investigate the effect of salinity (control, 1500 and 3000 ppm), seaweed extract at the rates of (250, 500 and 1000 ppm) and salicylic acid at the rates of (150, 300 and 450 ppm) on vegetative growth and chemical composition of *Plectranthus amboinicus* (Lour) Spreng plant. Rooted cuttings (10-15 cm length) of *Plectrunthus amboinicus* plants were planted on 10th March in the two seasons of 2015 and 2016 into 30 cm (diameter) plastic pots filled with a sand loamy soil. Physical and chemical properties of the used growing media were determined according to Jackson (1973) are shown in Table (A).

The saline irrigation water treatments were initiated the different saline water, concentration were prepared using a mixture of NaCl and $CaCl_2$ (1:1 w/w). The plants were irrigated two times per week with tap water 240-260 ppm (control) or saline water at concentrations of 0, 1500 and 3000 ppm. Plants receiving each of the tested salinity levels were sprayed 3 times with salicylic acid at concentrations of 0,150, 300 or 450 ppm or seaweed extract at concentrations of 0, 250, 500 or 1000 ppm. Control plants were sprayed with tap water.

Table (A): Physical and chemical analysis of the used soil in the experiment:

		First season	Second season
Physical analysis	Clay %	8.94	8.57
	Silt%	9.93	9.78
	Fine sand%	25.66	24.27
	Coarse sand%	55.47	52.38
	Soil texture	sand Loamy	sand Loamy
Chemical analysis	pH	7.71	7.61
	EC	5.85	3.20
	Available N (ppm)	141	135
	AvailableP_2O_5 (ppm)	202	200
	Available K_2O (ppm)	0.63	0.60
	Zn (ppm)	4.95	4.53
	Cu (ppm)	0.65	0.61
	B (ppm)	0.51	0.45
	Fe (ppm)	2.17	2.01
	Mn (ppm)	4.46	4.20

Table (B) Chemical and biochemical analyses of seaweed extract:

Organic matter		Elements contents	
Total amino acids	6%	Organic (N)	3.12 %
Carbohydrates	35%	P_2O_5	2.61 %
Alginic acid	10%	K_2O	4.71 %
Manitol	4%	Ca	0.25 %
Betaines	0.04%	S	3.56 %
Growth regulators		Mg	0.58 %
IAA	0.03%	Fe	150 ppm
Cytokinins(Adenine)	0.02%	Zn	70 ppm
		Mn	13 ppm
		B	60 ppm
		I	30 ppm

The plants were sprayed till run off. All other agricultural practices were carried out as usual in the two growing seasons. Chemical and biochemical analyses of seaweed extract are shown in Table (B).

Experimental design:

The layout of the experiment was factorial in randomized complete block design (RCBD), with three replicates; the first factor was the salinity treatments, whereas the second one was the seaweed extract or salicylic acid treatments. The experiment included 21 treatments with three replicates, every replicate was represented by 5 plants and every treatment represented by 15 plants. Regular agricultural practices such as weeding and watering… etc.

Data recorded:

The plants were harvested twice/season (first and second cuts) on June 7th and August 16th in both seasons, by cutting the herb of the plants at 10 cm above the soil surface and data were recorded as follows: fresh and dry weight of herb (g/plant), essential oil %was determined according British Pharmacopoeia (1963), essential oil yield(ml)/plant, GLC analysis of essenial oil in the first cut of the second season was performed using the methods described by Bunzen et al., (1969) and Hoftman (1967), total carbohydrates in leaves were determined using colorimetric method described by Smith et al., (1956), Nitrogen, Phosphorus, potassium and sodium % in leaves were estimated. Nitrogen was determined by microKjeldahle apparatus (Blake, 1965), Phosphorus was calorimetrically determined in the acid digested using ascorbic acid method (John and David 2000). Potassium was determined using the flame-photometer (Dewis and Freitas, 1970). Sodium percentage (% d.w.) in the nutrient extract was determined using a Pye Unicam (model SP 1900) atomic absorption spectrophotometer (Jackson, 1967). Proline content was determined in the fresh leaves according to Bates et al., (1973). Data were then tabulated and statistically analyzed using SAS computer program (1994) and means were performed by L.S.D test at the 5% level, according to Snedecor and Cochran (1968).

RESULTS AND DISCUSSION:

Effect of salinity, seaweed extract and salicylic acid on growth yield:

Fresh and dry weights (g/plant):

Data in Tables (1 and 2) showed that, *Plectranthus amboinicus* (Lour) spring plants were affected by all treatments (salinity, fertilizer treatments and its combinations) compared to control. The results indicated that all salinity concentrations significantly decreased fresh and dry weights/ plants as compared with tap water treatment. Salinity at the highest concentration gave the lowest values of fresh and dry weights in the two cuts of the two seasons. On the other hand, tap water treatment gave the highest values of fresh and dry herb weight. These results on decreasing herb production due to applying salinity are coincided with that reported by Bharti et al., (2014) on *Mentha arvensis*,Roodbari et al., (2013) on peppermint (*Mentha piperita* L.) and Zhou et al., (2018) on *Schizonepeta tenuifolia* Briq.

Table 1. Effect of salinity, seaweed extract and salicylic acid on fresh weight g/plant of *Plectranthus amboinicus* (Lour) Spreng plant during 2015 and 2016 seasons.

Salinity	First season 2015							
Treatments	First cut				Second cut			
	Tap water	1500 ppm	3000 ppm	Mean	Tap water	1500 Ppm	3000 ppm	Mean
Control	136.70	53.29	48.31	79.43	102.20	29.95	22.65	51.60
Sw1	136.40	69.46	54.08	86.65	111.80	61.68	49.41	74.30
Sw2	193.00	118.40	71.04	127.48	196.90	63.83	54.04	104.92
Sw3	196.30	119.90	73.30	129.83	199.00	64.40	51.97	105.12
Sa1	128.60	196.50	94.89	140.00	165.10	69.33	56.22	96.88
Sa2	190.90	193.10	102.00	162.00	217.90	68.82	57.98	114.90
Sa3	203.80	190.30	108.00	167.37	260.50	69.89	58.63	129.67
Mean	169.39	134.42	78.80		179.06	61.13	50.13	
LSD at 0.05 for								
Salinity	6.54				7.97			
Fertilizer	6.67				8.15			
Interaction	11.56				14.12			
Second season 2016								
Control	222.20	65.22	46.40	111.27	216.47	49.12	31.90	99.16
Sw1	372.40	104.80	72.03	183.08	244.17	52.87	47.03	114.69
Sw2	473.70	166.30	75.17	238.39	248.73	67.20	49.11	121.68
Sw3	481.20	182.90	75.70	246.60	298.82	91.13	53.63	147.86
Sa1	555.70	219.90	76.02	283.87	230.23	84.07	52.24	122.18
Sa2	669.70	265.80	76.37	337.29	241.85	97.31	55.70	131.62
Sa3	765.60	280.00	76.00	373.87	357.12	99.64	60.22	172.33
Mean	505.79	183.56	71.10		262.48	77.33	49.98	
LSD at 0.05 for								
Salinity	9.63				5.53			
Fertilizer	15.49				13.40			
Interaction	26.84				23.20			

Sw1: seaweed extract 250 ppm, Sw2: seaweed extract 500 ppm, Sw3: seaweed extract 1000 ppm, Sa1: salicylic acid 150 ppm, Sa2: salicylic acid 300 ppm and Sa3: salicylic acid 450 ppm.

Data in Tables (1 and 2) showed that, all rates of seaweed extract significantly increased fresh and dry weights of *Plectranthus amboinicus* (Lour) Spreng plants. A gradual increase was recorded in the herb depending on seaweed extract rate. The highest rate of seaweed extract (1000 ppm) was more effective for increasing the herb fresh and dry weights in the first and second cuts of both seasons compared with the control treatment. These results are in harmony with the results of Mahmoud (2016) on *Calendula officinalis* L. Eisa (2016) on sweet fennel plants and Abd El-Aleem et al., (2017) on Dutch fennel.

The data showed that, a stimulation effect was produced in *Plectranthus amboinicus* (Lour) Spring plants growth with using salicylic acid. This stimulation effect showed a gradual response due to increasing salicylic acid rates. So, the highest fresh and dry herb production was found in case of (450 ppm) of salicylic acid during the first and second cuts of both seasons compared to the control. These results agreed with Gharib (2007) on sweet basil and marjoram plants, Najafian et al., (2009) on *Thymus vulgaris* , Ibrahim (2010) on geranium, Badran et al., (2013)on guar, and Miri et al., (2015) on thyme, they reported that foliar application of SA significantly enhanced the vegetative characters i.e. fresh and dry weights.

Concerning interaction, the results in Tables (1 and 2) showed that, a significant effect was observed between the effects of salinity and treatments “seaweed extract and salicylic acid” on *Plectranthus amboinicus* growth in the two seasons. The highest increase was recorded in case of the tap water + salicylic acid (450 ppm), compared to the control plants.

Table 2. Effect of salinity, seaweed extract and salicylic acid on dry weight g/ plant of *Plectranthus amboinicus* (Lour) Spreng plant during 2015 and 2016 seasons.Sw1: seaweed extracts 250 ppm,

Salinity	First season, 2015							
Treatments	First cut				Second cut			
	Tap water	1500 ppm	3000 ppm	Mean	Tap water	1500 ppm	3000 ppm	Mean
Control	65.62	25.50	23.59	38.24	49.07	14.37	10.87	24.77
Sw1	72.73	36.82	25.89	45.15	53.64	16.33	17.18	29.05
Sw2	92.64	69.51	37.80	66.65	94.49	18.55	20.14	44.40
Sw3	94.24	70.44	39.07	67.92	95.44	21.78	20.79	46.00
Sa1	68.72	73.25	45.32	62.43	79.25	22.19	14.93	38.79
Sa2	91.65	77.24	54.10	74.33	80.38	23.64	18.62	40.88
Sa3	97.81	81.08	57.84	78.91	97.02	29.89	23.46	50.12
Mean	83.35	61.98	40.52		78.47	20.96	18.00	
LSD at 0.05 for								
Salinity	4.519				7.798			
Fertilizer	7.278				11.29			
Interaction	12.61				19.55			
Second season, 2016								
Control	86.21	12.39	12.34	36.98	74.25	17.91	10.21	34.12
Sw1	137.80	37.51	30.80	68.70	87.56	20.24	15.05	40.95
Sw2	178.32	65.18	40.73	94.74	82.31	26.04	15.72	41.36
Sw3	184.17	70.43	42.27	98.96	100.37	34.39	17.16	50.64
Sa1	213.44	87.96	37.20	112.87	72.71	33.63	16.72	41.02
Sa2	247.85	95.36	37.05	126.76	74.94	34.00	17.82	42.25
Sa3	271.82	99.82	42.56	138.07	115.71	39.86	19.27	58.28
Mean	188.52	66.95	34.71		86.84	29.44	15.99	
LSD at 0.05 for								
Salinity	4.842				5.186			
Fertilizer	9.795				5.644			
Interaction	16.97				9.776			

Sw2: seaweed extract 500 ppm, Sw3: seaweed extract 1000 ppm, Sa1: salicylic acid 150 ppm, Sa2: salicylic acid 300 ppm and Sa3: salicylic acid 450 ppm.

The previous results are in agreement with those of Nofal et al., (2015) on *Calendula officinalis* plant, and Salachna et al., (2015) on *Plectranthus ciliatus* plants reported that the application of salicylic acid increased the weight of the aboveground parts for growing plants under salinity, and salicylic acid seemed to relieve salinity-mediated plant stress.

Effect of salinity, seaweed extract and salicylic acid on Essential oil production:

Essential oil percentage in fresh herb.

Data presented in Table (3) indicated that salinity at the highest concentration gave the highest percentage of essential oil in the first cut of the first season and the two cuts in the second season. On the other hand, tap water treatment gave the highest percentage of essential oil in the second cut of the first season. These results agreed with Omar et al., (2013) on *Matricaria recutita* L., and Ali et al., (2014) on sage (*Salvia officinalis*) L., found that the higher level of soil salinity without amino acids gave the highest values of essential oil % and yield.

The treatments of seaweed extract and salicylic acid significantly increased the essential oil percentage in both seasons. The control treatment gave the lowest percentage of essential oil.

Table 3. Effect of salinity, seaweed extract and salicylic acid on oil percentage of *Plectranthusamboinicus* (Lour) Spreng plant during 2015 and 2016 seasons.

Salinity	First season, 2015							
Treatment	First cut				Second cut			
	Tap water	1500 ppm	3000 ppm	Mean	Tap water	1500 Ppm	3000 ppm	Mean
Control	0.033	0.023	0.032	0.029	0.040	0.020	0.025	0.028
Sw1	0.053	0.045	0.045	0.048	0.045	0.033	0.033	0.037
Sw2	0.053	0.052	0.042	0.049	0.052	0.033	0.035	0.040
Sw3	0.057	0.058	0.060	0.058	0.053	0.037	0.040	0.043
Sa1	0.060	0.060	0.065	0.062	0.062	0.033	0.052	0.049
Sa2	0.063	0.060	0.067	0.063	0.077	0.037	0.057	0.057
Sa3	0.067	0.063	0.083	0.071	0.083	0.037	0.060	0.060
Mean	0.055	0.052	0.056		0.059	0.033	0.043	
LSD at 0.05 for								
Salinity	0.002				0.008			
Fertilizer	0.016				0.011			
Interaction	0.019				0.013			
Second season, 2016								
Control	0.073	0.043	0.080	0.066	0.053	0.043	0.070	0.056
Sw1	0.077	0.050	0.097	0.074	0.053	0.043	0.083	0.060
Sw2	0.077	0.063	0.100	0.080	0.053	0.047	0.093	0.064
Sw3	0.080	0.073	0.107	0.087	0.057	0.047	0.100	0.068
Sa1	0.083	0.077	0.097	0.086	0.060	0.053	0.090	0.068
Sa2	0.080	0.077	0.103	0.087	0.067	0.050	0.103	0.073
Sa3	0.093	0.090	0.110	0.098	0.067	0.050	0.107	0.074
Mean	0.080	0.068	0.099		0.059	0.048	0.092	
LSD at 0.05 for								
Salinity	0.012				0.011			
Fertilizer	0.014				0.009			
Interaction	0.017				0.010			

Sw1: seaweed extract 250 ppm, Sw2: seaweed extract 500 ppm, Sw3: seaweed extract 1000 ppm, Sa1: salicylic acid 150 ppm, Sa2: salicylic acid 300 ppm and Sa3: salicylic acid 450 ppm.

These results are in agreement with Abd El-Wahab et al., (2016) on *Origanum vulgare* L., Eisa (2016) on sweet fennel, El-Gamal and Ahmed (2016) on dill and Tawfeeq et al., (2016) on *Rosmarinus officinalis* showed that seaweed extract increased oil percentage. On fennel, Gorni et al., (2017) and Ali et al., (2017) found that spraying plants with salicylic acid improved oil production.

Regarding interaction, the results in Table (3) showed that, a significant effect was observed between the effects of salinity and treatments of seaweed extract or salicylic acid on essential oil percentage in the two seasons. The highest increase was recorded in case of the salinity at (3000 ppm) +salicylic acid at(450 ppm) in all cuts, except the second cut of the first season the treatment of tap water plus salicylic acid 450 ppm gave the highest value compared to the control. Similar results were obtained by Miri et al., (2015) on thyme plants.

Oil yield of fresh herb/plant.

Data in Table (4) indicated that salinity at the highest concentration gave the lowest values of the essential oil yield/ plant in the first cut in both seasons; however salinity at the concentration of 1500 ppm gave the lowest values in the second cut of both seasons. On the other hand, tap water treatment gave the highest values of the essential oil yield/ plant in the two cuts of both seasons. Actually, these results are in agreement with Ozturk et al., (2004) on lemon balm (*Melissa officinalis* L.), reported that each increase in salt stress was accompanied with reduction in essential oil.Seaweed extracts gradually increased essential oil yield, exhibited significant promotive effects on oil yield/plant.

Table 4. Effect of salinity, seaweed extract and salicylic acid on oil yield (ml)/ plant of *Plectranthusamboinicus* (Lour) Spreng plant during 2015 and 2016 seasons.

Salinity	first season, 2015							
Treatment	First cut				Second cut			
	Tap water	1500 ppm	3000 ppm	Mean	Tap water	1500 ppm	3000 ppm	Mean
Control	0.046	0.012	0.015	0.024	0.041	0.006	0.006	0.018
Sw1	0.073	0.031	0.024	0.043	0.050	0.021	0.016	0.029
Sw2	0.103	0.061	0.030	0.065	0.102	0.021	0.019	0.047
Sw3	0.111	0.070	0.044	0.075	0.106	0.024	0.021	0.050
Sa1	0.077	0.118	0.062	0.086	0.102	0.023	0.029	0.051
Sa2	0.121	0.116	0.068	0.102	0.167	0.025	0.033	0.075
Sa3	0.136	0.121	0.090	0.116	0.217	0.026	0.035	0.093
Mean	0.095	0.076	0.048		0.112	0.021	0.023	
LSD at 0.05 for								
Salinity	0.027				0.045			
Fertilizer	0.019				0.052			
Interaction	0.018				0.021			
Second season, 2016								
Control	0.163	0.028	0.037	0.076	0.116	0.021	0.022	0.053
Sw1	0.285	0.053	0.070	0.136	0.130	0.023	0.039	0.064
Sw2	0.363	0.105	0.075	0.181	0.133	0.031	0.046	0.070
Sw3	0.385	0.134	0.081	0.200	0.170	0.043	0.054	0.089
Sa1	0.463	0.168	0.073	0.235	0.138	0.045	0.047	0.077
Sa2	0.536	0.204	0.079	0.273	0.161	0.049	0.057	0.089
Sa3	0.714	0.252	0.084	0.350	0.238	0.050	0.064	0.117
Mean	0.416	0.135	0.041		0.155	0.037	0.047	
LSD at 0.05 for								
Salinity	0.033				0.053			
Fertilizer	0.025				0.017			
Interaction	0.013				0.015			

Sw1: seaweed extract 250 ppm, Sw2: seaweed extract 500 ppm, Sw3: seaweed extract 1000 ppm, Sa1: salicylic acid 150 ppm, Sa2: salicylic acid 300 ppm and Sa3: salicylic acid 450 ppm.

The highest rate (1000 ppm) was more effective on increasing the essential oil yield/ plant in the first and second cuts of both seasons compared with the control treatment. These results are in harmony with the results of Abd El-Wahab et al., (2016) on *Origanum vulgare* and Tawfeeq et al., (2016) on *Rosmarinus officinalis*. Also, data in Table (4) indicated that, a stimulation effect was produced in the essential oil yield /plants with using salicylic acid. This stimulation effect shown by a gradual response due to increasing salicylic acid rates. So, the highest essential oil yield production was found in case of (450 ppm) of salicylic acid. These results agreed with Ibrahim (2010) on geranium plants concluded that salicylic acid at 300 ppm improved essential oil (% and yield) in both seasons, Marzok (2011) on clove basil plants and Miri et al., (2015) on thyme. Interaction between the effects of salinity and treatments of seaweed extract or salicylic acid had a significant effect on oil yield in the two seasons. The highest increase was recorded in case of the tap water + salicylic acid (450 ppm) compared to the control plants in both seasons.

Essential oil component:

Chromatographic analysis of oil samples extracted from *Plectranthus amboinicus* (Lour) Spring plant in the first cut of the second season, Table (5) showed that, the major essential oil component were β -Caryophyllene, Ƥ- cymene,α-humulene, terpineol, thymol, carvacrol, borneol and germacrene.

The data showed that salinity at 3000 ppm gave the highest mean values of Ƥ- cymene, β-caryophyllene (the major components) and α-humulene.

Table 5. Effect of salinity, seaweed extract and salicylic acid on oil components of *Plectranthus amboinicus* (Lour) Spreng plant in the first cut during 2016 season.

		β - Pinene	Myrcene	Ƥ- Cymene	γ- Terpinene	Terpineol	Borneol	Thymol	Carvacrol	β-Caryophyllene	α Humulene	Germacrene	Total
Tap water	Cont.	2.51	6.6	11.77	1.3	2.65	6.61	5.68	7.2	28.3	8.86	3.68	82.65
	SW1	4.45	14.27	9.65	2.08	9.65	4.09	6.39	4.14	32.03	5.60	3.62	91.52
	SW2	6.57	9.01	18.40	3.55	8.57	5.77	9.66	7.01	10.50	9.12	5.92	87.51
	SW3	4.90	12.97	11.15	3.24	8.44	4.96	9.85	5.87	15.97	8.79	4.46	85.7
	SA1	6.93	11.96	8.41	3.31	8.80	6.54	11.38	4.67	14.05	6.26	3.69	79.07
	SA2	2.64	1.15	18.52	4.93	9.60	7.26	13.06	7.64	6.81	12.70	4.83	86.5
	SA3	2.11	6.37	15.19	1.04	8.57	2.27	2.09	1.70	40.61	4.37	1.59	83.8
Mean		4.60	8.30	13.95	3.06	8.42	5.17	8.80	5.20	18.12	8.29	4.34	
1500 ppm	Cont.	4.35	8.23	14.60	3.25	8.70	5.58	7.74	7.40	16.67	10.46	5.15	87.78
	SW1	5.74	13.17	16.24	2.15	8.000	4.42	5.91	3.91	24.64	7.63	3.68	89.75
	SW2	7.52	9.82	9.59	---	7.10	5.91	15.02	5.71	21.75	10.43	4.75	90.08
	SW3	6.75	14.49	12.35	2.17	9.05	4.37	7.16	4.74	21.30	8.00	2.93	86.56
	SA1	5.68	13.36	10.54	3.25	8.58	5.24	10.20	6.09	15.70	7.77	4.65	85.38
	SA2	3.63	13.80	12.01	2.05	9.11	3.94	5.56	3.94	31.33	5.58	2.61	89.93
	SA3	2.17	3.50	11.41	2.67	9.58	6.30	6.50	5.48	31.83	9.92	3.70	90.89
Mean		5.12	10.91	12.39	2.59	8.59	5.11	8.30	5.32	23.32	8.54	3.92	
3000 ppm	Cont.	4.26	9.69	15.75	1.15	4.19	2.50	2.53	1.66	39.63	10.00	1.32	88.42
	SW1	1.2	4.74	5.40	0.93	5.04	1.92	1.67	1.29	64.63	5.94	0.87	92.43
	SW2	7.69	13.58	15.57	1.63	5.12	3.44	4.84	3.14	23.16	10.67	2.35	83.5
	SW3	5.50	12.89	13.49	0.80	6.84	2.46	3.93	1.81	39.20	7.27	1.62	90.31
	SA1	2.07	0.94	19.32	3.22	7.30	6.54	6.19	4.12	14.00	14.65	4.10	80.38
	SA2	6.37	13.20	15.89	2.03	7.77	4.62	6.42	3.93	21.91	10.97	2.63	89.37
	SA3	4.34	4.21	24.69	2.97	6.90	4.52	3.69	3.69	26.35	10.88	2.85	90.75
Mean		4.49	8.46	15.73	1.82	6.17	3.71	4.18	2.81	32.70	10.05	2.25	
Mean of Cont		3.71	6.23	14.04	1.90	5.18	4.90	5.32	5.42	28.20	9.77	3.38	
Mean of Sw1		3.80	10.73	10.43	1.72	7.56	3.48	4.66	3.11	40.43	6.39	2.72	
Mean of Sw2		7.26	10.80	14.52	2.59	6.93	5.04	9.84	5.29	18.47	10.07	4.34	
Mean of Sw3		5.72	13.45	12.33	2.07	8.11	3.93	6.98	4.14	25.49	8.02	3.00	
Mean of SA1		4.89	8.75	12.76	3.26	8.23	6.11	9.26	4.96	14.58	9.56	4.15	
Mean of SA2		4.21	9.38	15.47	3.00	8.83	5.27	8.35	5.17	20.02	9.75	3.36	
Mean of SA3		2.87	4.69	17.10	2.23	8.35	4.36	4.09	3.62	32.93	8.39	2.71	

Sw1: seaweed extract 250 ppm, Sw2: seaweed extract 500 ppm, Sw3: seaweed extract 1000 ppm, Sa1: salicylic acid 150 ppm, Sa2: salicylic acid 300 ppm and Sa3: salicylic acid 450 ppm.

On the other hand, the same treatment (3000 ppm) recorded the lowest mean values of γ-terpinene, terpineol, borneol, thymol, carvacrol and germacrene.

Regarding the effect of seaweed extract it was observed that, seaweed at the lowest rate (250 ppm) gave the highest total component (92.43%) under salinity at 3000ppm. Moreover, the highest mean value of β -caryophyllene (40.43%) was obtained from the treatment of seaweed at the lowest rate (250 ppm). On the other hand, it gave the lowest mean values of Ƥ- cymene, γ-terpinene, borneol, carvacrol and α- humulene.

The data also showed the effect of salicylic acid on oil composition. It was clear that, salicylic acid at the lowest rate (150 ppm) recorded the lowest total oil components (79.07%). It was also clear that, salicylic acid especially at the highest rate (450 ppm) recorded the lowest mean values of β- pinene, myrcene, thymol and germacrene.

Concerning the effect of interactions it was observed that, the highest value of β–caryophyllene (64.63%) was obtained from the treatment of the highest level of salinity (3000 ppm) combined with the lowest rate of seaweed (250 ppm).

3-Effect of salinity, seaweed extract and salicylic acid on chemical constituents:

a-Total carbohydrates content in the leaves:

Data presented in Table (6), indicated that, salinity had an effect on the total carbohydrates content in herb at the two cuts of both seasons as compared to the control (tap water).

Table 6. Effect of salinity, seaweed extract and salicylic acid on total carbohydrates percentage of *Plectranthus amboinicus* (Lour) Spreng plant during 2015 and 2016 seasons.

Salinity / Treatments	First season, 2015							
	First cut				Second cut			
	Tap water	1500 ppm	3000 ppm	Mean	Tap water	1500 Ppm	3000 ppm	Mean
Control	23.25	22.21	18.14	21.20	17.54	18.90	17.41	17.95
Sw1	23.29	23.04	19.7	22.01	23.14	20.57	18.20	20.64
Sw2	24.86	26.84	26.3	26.00	22.58	23.301	21.81	22.56
Sw3	25.73	26.17	27.74	26.55	22.84	23.93	23.58	23.45
Sa1	26.61	24.60	22.56	24.59	25.38	22.97	22.65	23.67
Sa2	30.12	25.29	23.74	26.38	25.81	24.50	24.33	24.88
Sa3	34.17	27.37	27.01	29.52	29.96	26.30	23.78	26.68
Mean	26.86	25.07	23.60		23.89	22.92	21.68	
Second season, 2016								
Control	25.90	23.09	22.16	23.72	22.58	19.94	18.50	20.47
Sw1	29.01	23.49	23.38	25.29	23.76	20.57	18.97	21.26
Sw2	35.00	23.82	23.77	27.53	26.98	21.04	21.39	22.98
Sw3	32.70	23.90	26.16	27.59	28.56	22.57	23.54	24.89
Sa1	32.50	25.90	22.58	26.99	31.68	27.00	20.32	26.21
Sa2	34.50	28.70	22.58	28.59	37.81	27.38	20.32	28.50
Sa3	35.70	35.00	25.68	32.13	38.10	29.78	23.11	30.33
Mean	32.19	26.27	23.76		29.92	24.04	20.88	

Sw1: seaweed extract 250 ppm, Sw2: seaweed extract 500 ppm, Sw3: seaweed extract 1000 ppm, Sa1: salicylic acid 150 ppm, Sa2: salicylic acid 300 ppm and Sa3: salicylic acid 450 ppm.

Plants received the highest concentration of salinity (3000 ppm), contained the lowest values of the total carbohydrates contents as compared to the other treatments. Whereas, the control plants gave the highest values of total carbohydrates contents. These results are in agreement with those obtained by Said -Al Ahl and Omer (2011) on some medicinal and aromatic plants, Ali et al., (2013) on *Simmondsia chinensis* and Mahmoud (2016) on *Calendula officinalis*.

Regarding the effect of seaweed extract treatments on the total carbohydrates content, data in Table (6) showed that, the different seaweed extract treatments increased the total carbohydrates contents as compared to the control. In both seasons in the two cuts, plants received seaweed extract at the rate of (1000 ppm) gave the highest total carbohydrates content. These results are in agreement with those obtained by Eisa (2016) on sweet fennel and Ragab (2016) on African marigold and Begonia.

The same trend was obtained from plants treated with salicylic acid, raising the level of salicylic acid resulted in a steady increase in total carbohydrates contents. Moreover, using salicylic acid at the highest rate (450 ppm), gave the highest total carbohydrates in the two cuts of both seasons compared with control.

Regarding the effect of interaction on total carbohydrates content, data indicated that,in both cuts of the two seasons,the highest values of total carbohydrates contents obtained from treatment of zero salinity combined with salicylic acid at the rate of 450 ppm. On the other hand, the lowest values of total carbohydrates contents were obtained from the treatment of control plants with saline water at the rate of 3000 ppm. These findings are in agreement with those obtained by Hashish et al., (2015) *Calendula officinalis* L. Khodary (2004) on maize (*Zea mays* L.) Concluded that SA treatment of salt stressed maize could stimulate their salt tolerance via accelerating their photosynthesis performance and carbohydrate metabolism.

b. Minerals content in the leaves:

The results presented in Tables (7,8,9 and 10), showed that different salinity concentrations decreased N,P and K contents in the leaves compared with control treatment which gave the highest N,P and K contents, while Na percentage was gradually increased with increasing salinity concentrations in both cuts of the two seasons.

Table 7. Effect of salinity, seaweed extract and salicylic acid on nitrogen percentage of *Plectranthus amboinicus* (Lour) Spreng plant during 2015 and 2016 seasons.

Salinity / Treatments	First season, 2015							
	First cut				Second cut			
	Tap water	1500 ppm	3000 ppm	Mean	Tap water	1500 ppm	3000 ppm	Mean
Control	1.99	1.62	1.45	1.69	1.93	1.94	1.88	1.91
Sw1	2.50	2.16	2.43	2.36	2.16	1.95	1.93	2.01
Sw2	2.49	2.16	2.49	2.38	2.16	2.06	1.98	2.07
Sw3	2.59	2.49	2.60	2.56	2.70	2.38	1.98	2.35
Sa1	1.97	2.06	1.73	1.92	2.27	1.95	2.00	2.07
Sa2	1.99	2.60	2.27	2.29	2.38	2.16	2.03	2.19
Sa3	2.66	2.60	2.60	2.62	2.71	2.27	2.13	2.37
Mean	2.31	2.24	2.22		2.33	2.10	1.99	
Second season 2016								
Control	2.08	2.16	2.06	2.10	2.16	2.06	2.02	2.08
Sw1	2.09	2.28	2.27	2.21	2.60	2.50	2.16	2.42
Sw2	2.36	2.40	2.40	2.38	2.77	2.53	2.32	2.54
Sw3	2.58	2.45	2.47	2.50	2.94	3.04	2.53	2.84
Sa1	2.55	2.50	2.46	2.50	2.80	3.02	2.14	2.65
Sa2	2.46	2.35	2.17	2.33	2.81	3.04	2.56	2.81
Sa3	2.59	2.48	2.48	2.52	3.26	3.09	2.74	3.03
Mean	2.39	2.37	2.33		2.76	2.75	2.35	

Sw1: seaweed extract 250 ppm, Sw2: seaweed extract 500 ppm, Sw3: seaweed extract 1000 ppm, Sa1: salicylic acid 150 ppm, Sa2: salicylic acid 300 ppm and Sa3: salicylic acid 450 ppm.

Table 8. Effect of salinity, seaweed extract and salicylic acid on phosphorus percentage of *Plectranthus amboinicus* (Lour) Spreng plant during 2015 and 2016 seasons.

Salinity / Treatments	First season, 2015							
	First cut				Second cut			
	Cont.	1500 ppm	3000 ppm	Mean	Cont.	1500 Ppm	3000 ppm	Mean
Control	0.24	0.28	0.10	0.21	0.19	0.14	0.12	0.15
Sw1	0.33	0.40	0.24	0.32	0.24	0.18	0.21	0.21
Sw2	0.36	0.49	0.31	0.39	0.26	0.31	0.27	0.28
Sw3	0.43	0.51	0.35	0.43	0.39	0.33	0.31	0.34
Sa1	0.29	0.22	0.20	0.24	0.23	0.19	0.23	0.22
Sa2	0.37	0.28	0.19	0.28	0.27	0.24	0.28	0.26
Sa3	0.55	0.54	0.35	0.48	0.45	0.42	0.31	0.39
Mean	0.37	0.39	0.25		0.29	0.26	0.25	
Second season 2016								
Control	0.25	0.21	0.17	0.21	0.22	0.20	0.17	0.20
Sw1	0.37	0.31	0.22	0.30	0.25	0.23	0.19	0.22
Sw2	0.50	0.37	0.23	0.37	0.31	0.26	0.20	0.26
Sw3	0.52	0.43	0.43	0.46	0.43	0.41	0.31	0.39
Sa1	0.22	0.22	0.28	0.24	0.42	0.29	0.24	0.32
Sa2	0.50	0.38	0.28	0.39	0.43	0.35	0.25	0.34
Sa3	0.55	0.34	0.40	0.43	0.47	0.41	0.35	0.41
Mean	0.42	0.33	0.29		0.36	0.31	0.24	

Sw1: seaweed extract 250 ppm, Sw2: seaweed extract 500 ppm, Sw3: seaweed extract 1000 ppm, Sa1: salicylic acid 150 ppm, Sa2: salicylic acid 300 ppm and Sa3: salicylic acid 450 ppm.

Table 9. Effect of salinity, seaweed extract and salicylic acid on potassium percentage of *Plectranthus amboinicus* (Lour) Spreng plant during 2015 and 2016 seasons.

Salinity / Treatments	First season, 2015							
	First cut				Second cut			
	Tap water	1500 ppm	3000 ppm	Mean	Tap water	1500 Ppm	3000 ppm	Mean
Control	2.18	2.18	1.87	2.07	3.66	3.31	1.91	2.96
Sw1	2.49	2.86	2.11	2.49	3.86	3.31	2.81	3.33
Sw2	3.00	2.18	2.24	2.47	4.28	3.62	2.10	3.33
Sw3	3.31	2.28	2.30	2.63	4.70	4.31	2.00	3.67
Sa1	2.97	2.27	2.28	2.50	4.65	4.49	2.05	3.73
Sa2	2.69	2.87	2.29	2.62	4.76	4.69	2.35	3.94
Sa3	3.83	2.59	2.31	2.91	4.80	4.74	2.40	3.98
Mean	2.92	2.46	2.20		4.39	4.07	2.23	
Second season, 2016								
Control	2.59	2.57	2.11	2.42	4.11	2.59	1.90	2.87
Sw1	3.52	3.22	2.94	3.23	5.52	3.31	2.00	3.61
Sw2	3.42	3.35	3.15	3.31	5.52	3.42	2.27	3.73
Sw3	3.93	3.45	3.26	3.55	5.24	4.24	2.29	3.92
Sa1	3.61	3.16	3.03	3.26	3.55	3.62	2.17	3.12
Sa2	4.35	3.93	3.35	3.88	5.21	3.83	2.39	3.81
Sa3	4.45	4.35	3.54	4.11	5.73	4.76	2.42	4.30
Mean	3.70	3.43	3.05		4.98	3.68	2.21	

Sw1: seaweed extract 250 ppm, Sw2: seaweed extract 500 ppm, Sw3: seaweed extract 1000 ppm, Sa1: salicylic acid 150 ppm, Sa2: salicylic acid 300 ppm and Sa3: salicylic acid 450 ppm.

Table 10. Effect of salinity, seaweed extract and salicylic acid on sodium percentage of *Plectranthus amboinicus* (Lour) Spreng plant during 2015 and 2016 seasons.

Salinity / Treatments	First season, 2015							
	First cut				Second cut			
	Tap water	1500 ppm	3000 ppm	Mean	Tap water	1500 Ppm	3000 ppm	Mean
Control	2.91	5.61	5.90	4.81	3.36	5.73	6.21	5.10
Sw1	2.81	5.50	5.82	4.71	2.71	4.88	6.00	4.53
Sw2	2.89	4.26	5.50	4.22	2.60	4.57	5.91	4.36
Sw3	2.64	4.05	5.19	3.96	2.40	4.16	5.89	4.15
Sa1	2.90	4.98	5.60	4.49	2.71	5.90	6.11	4.91
Sa2	2.72	4.26	4.57	3.85	2.49	4.57	5.88	4.31
Sa3	2.50	3.53	4.26	3.43	2.31	3.43	5.61	3.78
Mean	2.77	4.60	5.26		2.66	4.75	5.94	
Second season, 2016								
Control	2.99	4.16	5.60	4.25	2.41	4.88	6.09	4.46
Sw1	2.40	3.23	5.39	3.67	2.49	4.36	6.00	4.28
Sw2	2.47	2.82	4.77	3.35	2.51	4.36	5.89	4.25
Sw3	2.51	2.71	4.26	3.16	2.61	3.85	5.77	4.08
Sa1	2.50	4.08	4.39	3.66	2.51	5.08	5.80	4.46
Sa2	2.40	3.13	4.26	3.26	2.30	4.57	5.68	4.18
Sa3	2.30	2.31	3.82	2.81	2.20	4.57	5.48	4.08
Mean	2.51	3.20	4.64		2.43	4.52	5.82	

Sw1: seaweed extract 250 ppm, Sw2: seaweed extract 500 ppm, Sw3: seaweed extract 1000 ppm, Sa1: salicylic acid 150 ppm, Sa2: salicylic acid 300 ppm and Sa3: salicylic acid 450 ppm.

Similar results were obtained by El-Sayed (2013) on *Moringa oleifera*; Salachna et al., (2015) on *Plectranthus ciliates*,Matter (2015) on *Calendula officinalis* L. Abd El-Razek (2012) on *Echinacea paradoxa* and *Echinacea purpurea*.

Data also showed, the influence of the different seaweed extract treatments on increasing N,P and K contents compared to the control plants in both seasons, the highest percentages were found in plants received seaweed extract with the highest rate (1000ppm) in the first and second cuts of both seasons.Whereas seaweed extract treatments decreased Na percentage compared with control. These results are in agreement with Ragab (2016) on pot marigold *(Calendula officinalis*), African marigold (*Tagetes erecta*) and Begonia (*Begonia sempervirens*), and Eisa (2016) on sweet fennel.

Regarding the effect of salicylic acid, the results showed the effectiveness of the different salicylic acid treatments on increasing N, P and K percentages. salicylic acid at 450ppm gave the highest N,P and K percentages. While salicylic acid treatments decreased Na contents compared to the control in both two cuts of the two seasons. Moreover, the highest rate of salicylic acid (450 ppm) recorded the lowest sodium percentage against control in the first and second cuts, of the first and second seasons. These results were confirmed by Abdou et al., (2012a) on black cumin; Abdou et al., (2012b) on moghat and Badran et al., (2013) on guar (*Cyamopsis tetragonoloba*).This effect of salinity on sodium percentage was in agreement with the results reported by El-Sayed (2013) on *Moringa oleifera;* Salachna et al., (2015) on *Plectranthus ciliates* and Matter (2015) on *Calendula officinalis* L. Concerning, the effect of the interactions between salinity and other treatments (seaweed extract and salicylic acid) on the N,P and K percentages the combined treatments showed great effect during the two seasons compared to the control.

In both cuts of the two seasons, the treatment of tap water combined with salicylic acid at the rate of 450 ppm recorded the highest values N,P and K percentages. On the other hand, Salinity treatment at the highest concentration (3000 ppm) without spraying with seaweed extract or salicylic acid gave the highest Na percentages during the two cuts of both seasons. These results are similar to Ghasemi et al., (2016) on chamomile, Salachna et al., (2015) on *Plectranthus ciliatus*,Fatemi and Aboutalebi (2012) on Sweet basil (*Ocimum basilicum*)and Li et al., (2014)on *Artemisia annua* L.

c. proline content(mg/g)in herb:

From data recorded in Table (11), it could be concluded that, salinity treatments gradually increased proline content. The highest proline content was recorded by using the saline water at the rate of 3000 ppm in the two cuts of both seasons, whereas, control treatment obtained the lowest content. Similar results were obtained by Abd El-Razek (2012) on *Echinacea paradoxa* and *Echinacea purpurea;* Roodbari et al., (2013) on peppermint (*Mentha piperita* L.) and Matter (2015) on *Calendula officinalis* L.

The results in Table (11) also clearly showed that, seaweed extract gradually decreased proline content. In general, the highest rate of seaweed extract (1000 ppm) gave the lowest values of proline content comparing to control. Similar results were obtained by

Regarding the effect of salicylic acid on proline content, it could be concluded that, salicylic acid was the most effective in that concern. Accordingly, raising salicylic acid concentration resulted in progressive decrease in the recorded values compared to the control plants which had higher proline content in the two cuts of the both seasons. These results are in agreement with Omar et al., (2013) on *Matricaria recutita*, showed that increasing soil salinity significantly increased proline content.

Regarding the effect of interaction between the salinity and other treatments (seaweed extract and salicylic acid) on proline content of *Plectranthus amboinicus* (Lour) Spreng plant, data indicated that, in both cuts of the two seasons, the lowest values of proline content obtained from treatment of zero salinity combined with salicylic acid at the rate of 450 ppm. On the other hand, the highest values of proline content were obtained from the treatment of saline water at the rate of 3000 ppm plus control plants during the two cuts of the both seasons. Similar results were obtained by Salachna et al., (2015) on *Plectranthus ciliates* and ES-Sbihi et al., (2016) on *Mentha suaveolens.*

Proline is one of the important components of the adaptation of plants to salinity. The proline is the most important substance to regulate the osmotic tension in higher plants under abiotic stresses such as salinity, drought, heat and cold, the increase of the proline concentration is due to extensive protein degradation under abiotic stress such as drought (water deficit) and heat stress,Ghasemi et al., (2016)on chamomile.

Table 11. Effect of salinity, seaweed extract and salicylic acid on proline content(mg/g)of *Plectranthus amboinicus* (Lour) Spreng plant during 2015 and 2016 seasons.

Salinity / Treatments	First season, 2015							
	First cut				Second cut			
	Tap water	1500 ppm	3000 ppm	Mean	Tap water	1500 Ppm	3000 ppm	Mean
Control	0.20	0.36	0.56	0.37	0.30	0.39	0.61	0.43
Sw1	0.21	0.30	0.50	0.33	0.27	0.33	0.58	0.40
Sw2	0.22	0.23	0.43	0.29	0.27	0.30	0.46	0.34
Sw3	0.20	0.23	0.42	0.28	0.23	0.27	0.44	0.31
Sa1	0.21	0.29	0.46	0.32	0.27	0.30	0.49	0.35
Sa2	0.20	0.23	0.45	0.29	0.22	0.28	0.46	0.32
Sa3	0.18	0.23	0.41	0.27	0.20	0.26	0.44	0.30
Mean	0.20	0.27	0.46		0.25	0.31	0.50	
Second season, 2016								
Control	0.22	0.43	0.45	0.37	0.29	0.46	0.49	0.41
Sw1	0.16	0.40	0.45	0.34	0.27	0.42	0.47	0.39
Sw2	0.16	0.35	0.39	0.30	0.25	0.40	0.43	0.36
Sw3	0.16	0.35	0.37	0.30	0.21	0.40	0.41	0.34
Sa1	0.19	0.38	0.42	0.33	0.27	0.41	0.46	0.38
Sa2	0.18	0.36	0.38	0.31	0.21	0.36	0.42	0.33
Sa3	0.15	0.33	0.30	0.26	0.20	0.34	0.33	0.29
Mean	0.17	0.37	0.40		0.24	0.40	0.43	

Sw1: seaweed extract 250 ppm, Sw2: seaweed extract 500 ppm, Sw3: seaweed extract 1000 ppm, Sa1: salicylic acid 150 ppm, Sa2: salicylic acid 300 ppm and Sa3: salicylic acid 450 ppm.

CONCLUSION

From the above mentioned results it could be recommended to use seaweed extract or salicylic acid in case of using saline irrigation water to avoid the bad effect of salt stress on *Plectranthus amboinicus* (Lour) spring plant.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

All authors contributed equally in all parts of this Study.

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