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Research Article
Influences of Irrigation with Diluted Seawater and Fertilization on Growth, Seed Yield and Nutrients Status of *Salicornia* Plants

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Abstract

Background and Objectives: The feasibility of cultivating seawater depends on finding a germplasm resistance to salinity and developing appropriate agricultural techniques. Halophytes have the requisite salt tolerance and produce high biomass or seed yields under seawater irrigation. One of the promising halophytes is *Salicornia*. The purpose of this study was to evaluate production of *Salicornia* (*Salicornia bigelovii* L.) under irrigation with high saline water and influence of fertilization on growth, yield and nutrient content. **Materials and Methods:** A field experiment was conducted during 2018-2019. Four irrigation treatments (100% seawater, 50% seawater, 25% seawater and 100% well water) were running twice per week. A six fertilization treatments (control, algae extract as foliar and soil applications, NPK (20-20-20) alone or with micronutrients fertilizer (Fe+Mn+Zn+Cu in chelated form) and NPK+micronutrients fertilizer+algae extract were applied in combined with the four irrigation treatments. **Results:** The highest mean values of growth and seed yield of *Salicornia* plants were obtained by 50% dilution of seawater treatment. The treatment of algae extract soil with NPK+micronutrients fertilizers were produced the highest relative increase percentages in growth and yield. The combined treatment of NPK+micronutrients fertilizer+algae extract soil treatment in combined with 50% diluted of seawater was recorded the highest values of all parameters. **Conclusion:** Soil applied of algae extract as a bio-fertilizer with NPK+micronutrients fertilizers gave the highest increasing in *Salicornia* growth, yield and contents of nutrients, especially at 25 and 50% seawater dilution treatments.

Key words: *Salicornia*, seawater, well water, algae extract, NPK, micronutrient

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

One of the most problems facing the world is how to provide food needs in the frame of limiting soils for cultivation, not enough water sources with increasing population problem. Egypt, like other developing countries of the arid and semi-arid areas face four main problems: high population growth rate, limited natural resources for good quality water, presence of land affected by salt, lack of food and fodder[1].

The availability of water in many regions and most notably the Middle East and North Africa which have agricultural activities will be approaching the water crisis[2]. Therefore, it requires a change in the established agricultural operations management and taking the direction of non-traditional to maintain productivity and increase sustainability[3]. Halophytes which are tolerant to salinity can be grown and have usage in agricultural salt water recycling and sewage and salt-affected soil reclamation in irrigation areas in dry areas. Among these halophytes plants is *Salicornia bigelovii* L. which is multi-purpose crop, for the production of animal feed, oil and biofuel in the Northern West Desert land under both drought conditions and high salinity (soil and water) with limited water resources and the possibility of using of the diluted seawater for irrigation. The use of seawater to irrigate some salt tolerant crops has become one of the most interesting research points and getting the more attention from researchers, as one of alternatives that can partial solve the problem of shortage in the availability of irrigation water.

In this view, field studies have already been conducted in the Arabian Peninsula and Egypt in order to assess the suitability of coastal areas for the cultivation of *S. bigelovii* L.[4,5]. *Salicornia* has been recognized by many types of halophyte that have been tested for potential domestication due to the potential of field crops not only as oil seed, but also a new biomaterial for vegetable salt and herbal drug potentials[6].

Many studies have shown crop potentials for *S. bigelovii* L. in which areas they are characterized by hot and arid climatic conditions and its exceptional adaptation to coastal desert ecosystems[7,8]. Accordingly for successful cultivation, suitable *S. bigelovii* L. germplasm that has high productivity is adjustable to agricultural production and is economically viable, needs to be identified and advanced[9].

Seawater agriculture is the cultivation of salt-tolerant crops irrigated with diluted seawater in sandy soils of coastal deserts[8]. Many halophytes have explained noticeable flexibility in a wide range of high salinity levels because of immanent salt bearing[10,11]. *Salicornia* has advantage as an significant candidate over other halophytic species since it has demonstrated high yield, excessive salt tolerance[12] and has numerous potential utilize as a fresh or pickled vegetable, animal forage and a biofuel crop[8,13].

Ashour *et al.*[14] found that increasing seawater concentration in irrigation generally increasing succulence, proline content, sodium content, Na/K ratio, cell sap concentration (T.S.S.) and osmotic potential at different cuttings particularly with *Salicornia europaea* and *Leplochloa* at the level of 50% seawater treatment. In a greenhouse experiment, Batanouny *et al.*[15] studied the effect of irrigation with diluted seawater (12.5, 25.0, 37.0 and 50.0%) on the three halophytic plants e.g., *Sporobolus*, *Leplochloa* and *Salicornia europaea* where they found that increasing seawater concentration to the level of 25 and 37.5% (moderate salinity) generally increased the content of photosynthetic pigment, soluble carbohydrates and crude protein of the halophytic plants at the different cuttings.

Tawfik[16] pointed out that the nutritional status of the halophytes forages plants concentrated on the quantity of protein, phosphorus and plant content of produced energy. However, Ashour *et al.*[14] indicated that potassium is an serious nutrient and plays essentially role in water relations, osmotic regulation, stomatal motion and eventually plant resistance to drought, K^+ deficient plant has lower resistance to water stress. Nitrogen metabolism is the most serious factor that effect plant growth and efficiency, some studies showed the decrease of nitrate uptake and a reduction in nitrate reductase activity under water stress[17]. Improving the productivity, quality and ability of the new crop to tolerate the drought and salt stress conditions by using modern techniques (fertilization-fertilizers-irrigation).

Many types of research indicated the importance of using the algae as a bio-fertilizer vital to many different plant species in the new lands to overcome the difficult conditions such as; high alkaline degree, salinity and calcium content. Where, Cruz *et al.*[18] explained that using algae either soil or foliar usage conduct to improve the physiological status of plants and their efficiency to drought tolerance. Where, it has of all the nutrients and plant growth hormones which are fundamental for plants to improve yield[19-21]. However, Karthikeyan and Shanmugam[22] pointed out applied algae extract as foliar spray indicated relative increase 51% in seed yield.

In addition, El-Sayed *et al.*[23] showed that the foliar application of algae at a rate of 300 g/fed, achieved the highest values of fresh and dry weight (g/plant) and a remarkable increase of fresh and dry weight t/fed. Abd El-Baky *et al.*[24] cleared that the algae foliar extracts can

mend non-enzymatic and enzymatic antioxidant defense systems in potatoes plant cultivated under drought stress conditions.

In the arid regions, output of *Salicornia* seeds is very low (around 1-3 g/plant) because of high rivalry for space, nutrition and the moisture. The optimum plant per unit area and convenient dose of fertilization are most important parameters for increased crop output. No organized work has been aim so far. The using of seawater to irrigate some salt tolerant crops has become one of the most interesting research points and getting the more attention from researchers, as one of alternatives that can partial solve the problem of shortage in the availability of irrigation water.

The main objective of this work was to define and evaluate production of *Salicornia* under irrigation with high saline water and influence of fertilization on growth, yield and nutrient content.

MATERIALS AND METHODS

Experiment layout: A field experiment was conducted during 2018-2019 at Mariout district in Northern West of Egypt. The area of experiment was divided into 1 m^2 plots per replicate and plots were prepared and cultivated with *Salicornia bigelovii* Torr L. seedlings.

Treatments: Four irrigation treatments (100% seawater, 50% seawater, 25% seawater and 100% well water) with EC 51.0, 30.0, 16.6 and 2.4 ds m^{-1}, respectively, were run two times per week during March, April, May and June and then three times/ week till September by addition of 5-10 L depends on the plants requirement/plot. A six fertilization treatments (control, algae extract as foliar and soil applications (the chemical composition of algae extract shown in Table 1, NPK (20-20-20)+micronutrients fertilizer (Fe 3%+Mn 3%+Zn 3%+Cu 0.5% in chelated form) and NPK+micronutrients fertilizer+algae extract) were applied each two weeks in rate of 2 g L^{-1} (started from 1st May until 15th July) in combined with the four irrigation treatments.

Experiment design: The treatments were arranged in split plot design with 3 replicates where the main plots were devoted to the 4 irrigation treatments. The sub-plots were randomly devoted to the 6 fertilization treatments.

Data recorded: Experimental soil (depth 0-30) was analyzed according to the method described by Jackson[25] and having the following characteristics: texture was sandy with EC 3.64 dS m^{-1}, pH 8.2, calcium carbonate 18.8%, organic matter 0.08%, K 76, Ca 26, Mg 136, Na 960, Fe 6.4, Mn 6.8, Zn 2.6 and Cu 1.3 ppm. During the cropping season, lowest minimum temperature was 15°C, maximum temperature reached 40°C and relative humidity was always more than 50%. The growth parameters; plant height (cm), fresh and dry weight (g m^{-2}) were determined at harvest. Also, plants contents of macro and micro-nutrients were determined by methods described by Cottenee *et al.*[26]. At harvest seed yield was estimated per plot and seeds contents of macro and micro-nutrients were determined.

Statistical analysis: Data collected were subjected to the proper statistical analysis with the methods described by Snedecor and Cochran[27] to compare the means, the Least Significant Differences (LSD) were used.

Table 1: Chemical composition, mineral content, amino acids content and HPLC chromatogram hormones of algae extract

	Percentage						ppm			
Elements	N	P	K	Mg	Na	Ca	Fe	Zn	Mn	Cu
Concentration	13.30	2.22	2.13	0.22	0.01	0.33	1936.00	68.00	21.00	18.00
		Indole acetic acid			Indole butyric acid					Gibberellic acid
Hormones (mg g^{-1})		13.66			3.25					1.19
Amino acid		Concentration (%)			Amino acid					Concentration (%)
Amino acid content (%)										
Aspartic		1.85			Threonine					0.83
Serine		0.70			Glutamic					2.24
Proline		0.67			Glycine					1.07
Alanine		1.55			Valine					1.11
Methionine		0.33			Isoleucine					0.71
Leucine		0.29			Tyrosine					0.53
Phenylalanine		0.87			Histidine					0.24
Lysine		0.70			Arginine					0.98
Cysteine		0.22								
Total amino acids										15.89

RESULTS

Effect of irrigation alone (four irrigation treatments of seawater dilutions) and in combined with fertilization (algae extract, NPK and micronutrients) on some growth parameters, seeds yield and nutrient contents of *Salicornia* plants cultivated in the field experiment were illustrated in Table 2-4.

Growth parameters and seed yield

Effects of irrigation treatments (seawater dilution treatments): Data of the vegetative growth parameters and seed yield of *Salicornia* plants grown under the effect of applied irrigation treatments with diluted of seawater were presented in Table 2. The obtained results showed that there were no significant differences between irrigation treatments for plant height whereas, fresh weight, dry weight and seed yield showed remarkable significant differences. The highest mean values were 2781, 1328 and 286 g m^{-2} for fresh weight, dry weight and seed yield, respectively at 50% dilution of seawater. The lowest mean values of fresh weight, dry weight and seed yield were recorded at 100% dilution of seawater treatment.

Effects of fertilization treatments: Data in Table 2 showed that growth parameters and seed yield of *Salicornia* plants increased significantly with all fertilization treatments.

Data cleared that the highest mean values of plant height, fresh weight, dry weight and seed yield were obtained by NPK+micro+algae extract soil treatment compared with control.

On the other hand, applying of algae extract as a bio-fertilizer with NPK+micronutrients fertilizers treatment gave

Table 2: Mean effect of irrigation and fertilization treatments and their interactions on growth character and seed yield of *Salicornia* plants during 2018-2019

Treatments		Growth characters			
Irrigation	Fertilization	Plant height (cm)	Fresh weight (g m^{-2})	Dry weight (g m^{-2})	Seed yield (g m^{-2})
100% seawater	Control	50.8	1753	666	128
	Algae extract foliar	51.7	2024	708	152
	Algae extract soil	53.4	2302	1105	227
	NPK soil	54.6	2140	1241	169
	NPK soil+micro	54.8	2263	1077	210
	NPK soil+micro+algae extract soil	55.3	2590	1398	245
50% seawater+50% well water	Control	51.3	2180	959	165
	Algae extract foliar	52.8	2550	1275	195
	Algae extract soil	55.1	3128	1501	392
	NPK soil	54.9	2587	1294	215
	NPK soil+micro	56.3	3022	1360	334
	NPK soil+micro+algae extract soil	60.8	3218	1576	413
25% seawater+75% well water	Control	52.5	2156	970	163
	Algae extract foliar	53.2	2505	1303	191
	Algae extract soil	58.1	3091	1483	305
	NPK soil	55.0	2595	1245	200
	NPK soil+micro	58.9	2999	1352	285
	NPK soil+micro+algae extract soil	59.1	3144	1509	326
100% well water	Control	51.6	1980	837	151
	Algae extract foliar	53.5	2438	951	178
	Algae extract soil	54.0	3050	1373	256
	NPK soil	53.8	2633	1067	192
	NPK soil+micro	56.8	2921	1081	245
	NPK soil+micro+algae extract soil	57.5	3071	1290	295
Mean values of irrigation	100% seawater	53.4	2179	1033	189
	50% seawater+50% well water	55.2	2781	1328	286
	25% seawater+75% well water	56.1	2748	1310	245
	100% well water	54.5	2682	1100	220
Mean values of fertilizers	Control	51.6	2017	858	152
	Algae extract foliar	52.8	2379	1059	179
	Algae extract soil	55.2	2893	1366	295
	NPK soil	54.6	2489	1212	194
	NPK soil+micro	56.7	2801	1218	269
	NPK soil+micro+algae extract soil	58.2	3006	1443	320
LSD at 5% irrigation treatments		NS	163	76	27
LSD at 5% fertilization treatments		3.7	187	91	32
LSD at 5% interaction of irrigation×Fertilization treatments		4.1	213	110	38

Table 3: Mean effect of irrigation and fertilization treatments and their interactions on nutrients content of *Salicornia* plants during 2018-2019

Treatments		Percentage						ppm			
Irrigation	Fertilization	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
100% seawater	Control	0.81	0.16	2.05	2.25	0.95	15.40	157	38	48	43
	Algae extract foliar	0.78	0.20	2.20	2.60	1.26	17.00	212	59	66	8
	Algae extract soil	0.86	0.07	2.10	2.20	0.82	15.00	137	42	45	25
	NPK soil	0.95	0.06	1.60	1.40	1.08	8.50	247	44	16	9
	NPK+micro soil	1.08	0.10	2.00	2.50	0.95	15.30	156	51	80	32
	NPK+micro+algae extract soil	1.22	0.10	2.15	2.40	0.79	13.30	160	46	52	79
50% seawater+50% well water	Control	0.83	0.14	2.45	2.25	0.69	14.15	128	36	40	19
	Algae extract foliar	0.82	0.13	2.30	2.50	0.87	15.30	251	55	64	9
	Algae extract soil	1.18	0.13	2.25	2.30	0.75	14.40	164	42	74	31
	NPK soil	1.41	0.06	1.70	1.30	1.11	7.00	232	39	23	13
	NPK+micro soil	1.43	0.14	1.95	2.35	0.71	13.50	147	50	68	30
	NPK+micro+algae extract soil	1.32	0.13	2.05	2.90	0.89	14.05	198	53	66	24
25% seawater+75% well water	Control	1.18	0.10	2.30	2.35	0.65	11.50	120	28	31	48
	Algae extract foliar	0.78	0.09	2.10	2.40	0.94	14.30	205	45	74	7
	Algae extract soil	1.33	0.13	2.15	2.35	0.81	13.80	145	38	53	45
	NPK soil	1.42	0.06	2.30	1.50	1.13	6.75	176	34	25	10
	NPK+micro soil	1.45	0.12	1.85	2.35	0.86	13.00	151	40	63	47
	NPK+micro+algae extract soil	1.72	0.12	2.05	2.55	0.72	12.65	161	46	86	55
100% well water	Control	0.80	0.14	2.55	2.50	0.72	13.90	147	21	43	15
	Algae extract foliar	0.74	0.09	2.60	2.70	1.13	15.50	163	45	61	4
	Algae extract soil	1.13	0.13	2.05	2.55	0.88	13.05	213	38	58	22
	NPK soil	1.37	0.02	1.60	1.50	0.86	6.50	252	30	18	13
	NPK+micro soil	1.41	0.12	2.55	2.70	0.87	14.55	151	41	75	8
	NPK+micro+algae extract soil	1.33	0.08	2.50	2.90	0.99	12.65	222	46	76	42
Mean values of irrigation	100% seawater	0.95	0.12	2.02	2.23	0.98	14.08	178	47	51	33
	50% seawater+50% well water	1.17	0.12	2.12	2.27	0.84	13.07	187	46	56	34
	25% seawater+75% well water	1.31	0.10	2.13	2.25	0.85	12.00	160	39	55	44
	100% well water	1.13	0.10	2.31	2.48	0.91	12.69	191	37	55	12
Mean values of fertilizers	Control	0.91	0.14	2.34	2.34	0.75	13.74	138	31	41	31
	Algae extract foliar	0.78	0.13	2.30	2.55	1.05	15.53	208	51	66	7
	Algae extract soil	1.13	0.12	2.14	2.35	0.82	14.06	165	40	58	31
	NPK soil	1.29	0.05	1.80	1.43	1.05	7.19	227	37	21	11
	NPK+micro soil	1.34	0.12	2.09	2.48	0.85	14.09	151	46	72	29
	NPK+micro+algae extract soil	1.40	0.11	2.19	2.69	0.85	13.16	185	48	70	50
LSD at 5% irrigation treatments		0.08	NS	0.15	Ns	Ns	0.51	23	NS	NS	4
LSD at 5% fertilization treatments		0.12	0.03	0.21	Ns	Ns	0.62	29	13	21	6
LSD at 5% interaction of irrigation × Fertilization treatments		0.17	0.04	0.27	Ns	Ns	0.70	37	16	25	11

mean of seed yield (320 g m^{-2}) with a percentage increase (111%) more than twice comparing with control treatment (152 g m^{-2}). In addition, applying algae extract as soil application were more effective by 1.2, 1.3 and 1.6 times than as foliar for fresh weight, dry weight and seed yield, respectively.

Interaction effect between irrigation and fertilization treatments: The interaction effect between four irrigation and six fertilization treatments on vegetative growth parameters and seed yield of *Salicornia* plants was significant, as illustrated in Table 2. The highest values of plant height, fresh weight, dry weight and seed yield were observed by NPK+micro foliar+algae extract soil treatment combined with 50% diluted seawater treatment.

Nutrients status

Effects of irrigation treatments (seawater dilution treatments): There is significant differences between irrigation treatments on nutrients content of *Salicornia* plants and seeds for N, K, Na, Fe and Cu content in plants and N, K Ca, Na, Fe and Zn content in seeds as shown in Table 3 and 4.

Data in Table 3 revealed that the highest content values in plants from N and Cu were produced by dilution of seawater at 25%, K at 100% well water and Na, Fe at 100% seawater.

Meanwhile, the highest values of N, K and Ca in seeds were obtained by dilution of seawater at 25% and Na, Fe and Zn seed contents were at 100% seawater as shown in Table 4.

Effects of fertilization treatments: The effect of applied fertilization treatments were significantly for both plants and seeds element content of *Salicornia*, except Ca, Mg in plant and Mg, Cu contents in seeds. The results were illustrated in Table 3 and 4.

It is worthy to observe in Table 3 that N content in plants increased with different fertilizers and the highest value 1.40% (with increase of 54% compared to the control) was by NPK+micro foliar+algae extract soil treatment, but the reverse was true for P (0.11%) and K (2.19%) contents.

However, Ca and Mg content in plants seemed to be without effect with these treatments, while Na content decreased with NPK treatment and NPK+micro foliar+algae extract soil compared with the others treatment.

Micronutrients content in plants, especially Fe, Mn and Zn increased with all fertilization treatments, except NPK treatment compared to the control (Table 3).

On the other hand, N, P and K content in seeds of *Salicornia* increased with different fertilizers in comparing with control. Data in Table 4 indicated that, NPK+micro foliar+algae extract soil treatment produced the highest relative increase percentages in N, P and K content in seeds of *Salicornia* which were 51, 50 and 45%, respectively compared with control treatment. While, NPK+micro treatment produced the highest relative increase percentages in Na, Fe, Mn and Zn content in seeds of *Salicornia* which were 10, 75, 139 and 450%, respectively compared with control treatment.

Table 4: Mean effect of irrigation and fertilization treatments and their interactions on nutrients content of *Salicornia* seeds during 2018-2019

Treatments		Percentage						ppm			
Irrigation	Fertilizers	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
100% seawater	Control	0.63	0.08	2.6	1.1	1.03	5.9	281	38	12	8
	Algae extract foliar	0.68	0.09	2.7	1.3	1.00	5.8	298	42	20	7
	Algae extract soil	1.01	0.14	3.3	1.3	1.07	5.0	524	75	52	7
	NPK soil	1.14	0.11	3.8	1.5	1.22	3.5	431	70	57	8
	NPK+micro soil	1.11	0.15	3.7	1.5	1.07	5.8	466	73	90	10
	NPK+micro+algae extract soil	1.18	0.15	4.0	1.1	1.10	5.8	519	79	48	9
50% seawater+50% well water	Control	0.67	0.10	2.9	1.3	0.97	5.7	272	37	13	6
	Algae extract foliar	0.72	0.11	2.9	1.4	1.10	5.6	285	40	25	5
	Algae extract soil	1.10	0.11	3.9	1.9	1.06	5.5	416	59	41	8
	NPK soil	1.14	0.16	3.9	1.4	1.04	5.8	453	64	43	10
	NPK+micro soil	1.18	0.14	4.5	1.7	1.10	7.3	484	65	48	11
	NPK+micro+algae extract soil	1.18	0.18	4.5	1.8	0.97	6.0	283	57	32	8
25% seawater+75% well water	Control	1.06	0.11	3.2	1.4	0.98	4.8	253	30	15	7
	Algae extract foliar	0.91	0.11	3.4	1.5	1.15	5.5	271	36	29	7
	Algae extract soil	1.10	0.10	4.0	1.6	0.96	4.8	320	56	72	7
	NPK soil	1.25	0.13	4.4	1.3	1.10	6.0	332	67	45	8
	NPK+micro soil	1.32	0.16	3.4	1.4	1.02	4.8	455	98	56	9
	NPK+micro+algae extract soil	1.18	0.20	4.2	1.8	1.13	6.8	415	109	92	12
100% well water	Control	0.86	0.11	3.0	1.4	1.10	4.2	229	28	14	5
	Algae extract foliar	0.88	0.10	3.1	1.5	1.10	5.2	242	33	23	8
	Algae extract soil	1.49	0.11	3.4	1.7	1.13	4.7	463	76	71	12
	NPK soil	1.06	0.14	4.0	1.9	1.16	5.5	412	73	43	11
	NPK+micro soil	1.49	0.16	3.5	1.9	0.93	4.8	401	78	57	10
	NPK+micro+Algae extract soil	1.33	0.08	4.3	1.2	1.21	3.8	276	62	37	8
Mean values of irrigation	100% seawater	0.96	0.12	3.35	1.30	1.08	5.30	420	63	47	8
	50% seawater+50% well water	1.00	0.13	3.77	1.58	1.04	5.98	366	54	34	8
	25% seawater+75% well water	1.14	0.14	3.77	1.50	1.06	5.45	341	66	52	8
	100% well water	1.19	0.12	3.55	1.60	1.11	4.70	337	58	41	9
Mean values of fertilizers	Control	0.81	0.10	2.93	1.30	1.02	5.15	259	33	14	7
	Algae extract foliar	0.80	0.10	3.03	1.43	1.09	5.53	274	38	24	7
	Algae extract soil	1.18	0.12	3.65	1.63	1.06	5.00	431	67	59	9
	NPK soil	1.15	0.14	4.03	1.53	1.13	5.20	407	69	47	9
	NPK+micro soil	1.28	0.15	3.78	1.63	1.03	5.68	452	79	63	10
	NPK+micro+algae extract soil	1.22	0.15	4.25	1.48	1.10	5.60	373	77	52	9
LSD at 5% irrigation treatments		0.07	NS	0.30	0.10	NS	0.40	28	NS	2	NS
LSD at 5% fertilization treatments		0.11	0.02	0.40	0.20	NS	0.50	35	18	3	NS
LSD at 5% interaction of irrigation×Fertilization treatments		0.16	0.03	0.50	0.30	NS	0.60	41	22	4	5

Interaction effect between irrigation and fertilization treatments: All calculated of element content of *Salicornia* plants and seeds affected significantly by the interaction between the two studied factors (irrigation×fertilization), except Ca and Mg contents in plants and Mg content in seeds as shown in Table 3 and 4. Also, data represented in Table 3 and 4 showed that the highest mean values of N, P, K, Na, Fe, Mn, Zn and Cu content in *Salicornia* plants and seeds enhanced especially at 50 and 25% seawater dilution treatments with applying of algae extract soil application as a bio-fertilizer with or without NPK+micronutrients fertilizers treatment.

DISCUSSION

Study the effect of irrigation and fertilization treatments and their interactions on growth and nutrients content of *Salicornia* plants under five fertilizations treatments of green algae extract, NPK and micronutrients fertilizers which used as source of nutrients and as growth stimulators which decrease the effect of salinity, in addition to control and in combined with four irrigation treatments concerning different dilution of seawater.

The results were confirmed by many investigators as follows: Ashour *et al.*[14] reported that increasing seawater concentration in irrigation generally increasing succulence, proline content, sodium content, Na/K ratio, T.S.S. and osmotic potential at different cuttings, particularly with *Salicornia europaea* at the level of 50% seawater treatment to maintain the effects of saline conditions and stress. In a greenhouse experiment, Batanouny *et al.*[15] studied the effect of irrigation with diluted seawater (12.5, 25.0, 37.0 and 50.0%) on *Salicornia europaea* where they found that increasing seawater concentration to the level of 25 and 37.0% (moderate salinity) generally increased the content of photosynthetic pigment, soluble carbohydrates and crude protein to increase plant resistance, growth and yield under salinity stress.

On the other hand, Tawfik[16] pointed that nutritional status of the halophytes forage plants concentrated on quantity of protein, phosphorus and plants content of produced energy. However, Ashraf *et al.*[28] reported that, potassium is serious nutrient and plays essentially role in water relations, osmotic regulation, stomatal motion and eventually plant resistance to drought, K^+ deficient plant has lower resistance to water stress. Nitrogen metabolism is the most serious factor that effect plant growth and efficiency, some studies showed the decrease of nitrate uptake and a reduction activity under water stress[17].

However, Pandya *et al.*[29] pointed that *Salicornia* fertilization with N increased growth and seed yield. Also, found that increasing doses of fertilization by phosphorus up to 75 kg ha^{-1} increased seed yield. In the case of interaction between N and P seed yield increased at the highest level of fertilization. Application of N significantly increased the content of N in both *Salicornia* plants and seeds and potassium uptake and content were also increased as a result of symbiosis with N. Nitrogen and potassium were found to increase with the application of P. For that fertilization *Salicornia* with NPK is very important to enhance metabolism, physiological and biochemical functions inside the cell to be able to maintain the effects of salinity stress.

Many researches indicated the importance of using the algae as a fertilizer vital to many different plant species in the new lands to overcome the difficult conditions such as; high of alkaline degree, salinity and content of calcium carbonate. Where, Cruz *et al.*[18] cleared that using algae either soil or foliar application lead to improve the physiological status of plants and their ability to drought tolerance. In addition, El-Sayed *et al.*[23] showed that the foliar application of algae at a rate of 300 g/fed achieved the highest values of fresh and dry weight (g/plant) and a remarkable increase of fresh and dry weight t/fed. El-Nasharty *et al.*[20] and El-Nwehy *et al.*[21] found that treatment of algae extract with micronutrients fertilizer increased plant height, fresh and dry weight, seed yield, oil percent and nutrient content compared with control. In this connection, Abd El-Baky *et al.*[24] explained that the algae foliar extracts application with the rate 300 g/fed can improve non-enzymatic and enzymatic antioxidant defense systems in plants cultivated under drought and salinity stress conditions.

These beneficial effects of algae extract on growth, yield and nutrient content of *Salicornia* plants due to it contains growth promoting hormones like Auxins, Gibberellins, Cytokinin, Proline, Abscisic acid, Ethylene, Betaine and Polyamines other than the trace elements, vitamins, amino acids, antibiotics and nutrients[30]. As shown in Table 1, Abdel Aziz *et al.*[31] found that irrigated plants with 1000 ppm saline water and spraying with 2.5 cm^3 L^{-1} algae extracts gave the highest values of fresh and dry weight of plants. Dehnavi and Sheshbahre[32] noted that proline increased plants ability to tolerate stress and enhancing plants growth under stress condition. Hormones such as Indole Acetic Acid (IAA), gibberellic acid (GA3) and kinetin (Kin) are known to be involved in the regulation of plant response to salinity stress and counteract the adverse effect of stress conditions[33].

It can be concluded that algae extracts application enhances plant tolerance against salinity because it increase

the biochemical constituents of plants and possess environmental stress mitigating potential. Amendment of algae extract fertilizer to soils improves the soil health by enhancing the micronutrient quantity and quality and microbial activity.

CONCLUSION

The productivity, quality and ability of *Salicornia* plants as a new crop to tolerate the drought and salt stress conditions were improved by using modern techniques (fertilization-fertilizers-irrigation). It is concluded that fertilization of *Salicornia* with soil application of algae extract as a bio-fertilizer with NPK+micronutrients fertilizers gave the highest increasing of *Salicornia* growth, yield and contents of all macro and micro-nutrients, especially at 50 and 25% seawater dilution treatments. But with 50% seawater dilution gave the highest values of seed yield (413 g m^{-2}), in Northwest Coast of Egypt.

SIGNIFICANCE STATEMENT

This study discovers the *Salicornia* plants as a new crop to tolerate the drought and salt stress conditions in arid and semi-arid land that can be beneficial for increasing its productivity and quality by using modern techniques (fertilization-fertilizers-irrigation) under these environmental conditions. This study will help the researcher to use salt water in the sandy soils of coastal deserts as an alternative source of crops to provide food needs with increasing population problem. Thus, a new theory on cultivation of *Salicornia* with soil application of algae extract as a bio-fertilizer with NPK+micronutrients fertilizers gave the highest increase of *Salicornia* growth, yield and contents of all macro and micro-nutrients, especially at 50 and 25% seawater dilution treatments in Northwest Coast of Egypt.

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