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Sustainable production of *Kochia indica* grown in saline habitat

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Abstract

Biosaline agriculture is considered as unconventional approach for sustainable use of marginal soil (salt affected soils with poor drainage) and salt affected irrigation water. These can be used for planting non-traditional crops such as halophytic plants to overcome the serious shortage of fresh water and conventional soil. To achieve the aforementioned objectives, two field experiments were carried around Qaroon lake, Fayum Governorate, Egypt at the two successive summer season of 2011 - 2012 to study the effect of foliar application of zinc, potassium or ascorbic acid in addition to fresh water as control on vegetative growth and some physiochemical parameters of *Kochia indica* grown under diluted saline water (Fresh water, 25% and 50%) from Qaroon Lake. Irrigation with 25% dilution significantly increased plant growth compared to fresh water irrigation. Raising irrigation salinity levels up to 50% significantly increase the content of chlorophyll a+b, proline, soluble carbohydrates and osmotic potential values compared to fresh water. On the other hand, the same treatment decreased the content of potassium and zinc in the shoot of *K inica* plant. However moderate saline irrigation i.e. 25 % generally increased crude protein content. All foliar spraying treatments significantly increased plant height, number of branched/plant, leaf area, shoot dry weight, root dry weight, chlorophyll a+b, crude protein, potassium and zinc as well as (salinity tolerance index) STI and succulence values as compared with control plants. On the other hand, foliar treatments decreased the content of soluble carbohydrates, proline and osmotic potential values. As for the interaction effect of between saline irrigation and foliar treatments, data show that the highest content of crude proten % and photosynthetic pigments were recorded in *Kochia indica* plants sprayed with 2% KNO_3 and irrigated with 25% Lake water, meanwhile plants sprayed with 300 ppm Zn-EDTA and irrigated with fresh water produced the highest zinc content. Furthermore, plants sprayed with fresh water and irrigated with 50% Lake water produced the highest content of soluble carbohydrates and proline as well as succulence and osmotic potential values. In conclusion, Foliar application with potassium surpasses all the other treatments especially under high levels of saline irrigation.

Key words: *Kochia indica* - Biosaline agriculture – Foliar treatments.

1. Introduction

Throughout North African coastline, there are extensive coastal salt affected deserts where seawater is the only water available. Although growing crops in salt affected sandy soil and salty water is not a common prospect for most farmers, for saline agriculture they can complement each other. The disadvantages of sandy soil for conventional crops become advantages when saline water and salt tolerant plants are used.

Salt tolerant plants (halophytes) are highly evolved and specialized organisms. They have well-adapted morphological, phonological and physiological characteristics allowing them to proliferate in the high salinity conditions and offer a low-cost approach to reclaiming and rehabilitating saline habitats [1, 2]. This approach would lead to the domestication of wild, salt tolerant plants for use as forage crops [3, 4]. Whereas, *Kochia indica* is a highly salt tolerant annual halophytic forage plant grown well in coastal salt marsh in Egypt. However, few forage halophytes have been domesticated and hence special management practices for their cultivation, adaptation and new agronomic traits must be developed and tested [5]. Many authors investigated the benefits of *Kochia indica* as feed for livestock [6] and as solution for salinization [4].

Currently, foliar-applied nutrients have limited direct use for enhancement of stress resistance mechanisms in field crops. Nevertheless, the interactions between plant nutrient levels and stress repair mechanisms are now being studied [7]. Foliar application of potassium during vegetative growth is one of these precautions. Potassium is essential in maintenance of osmotic potential and water uptake and had a positive impact on stomatal closure which increase tolerance to water stress [8]. Moreover, it is involved in activating a wide range of enzyme systems which regulate photosynthesis, water use efficiency and movement, nitrogen uptake and protein building [9]. While, zinc is an component of a number of dehydrogenases, proteinases and peptidases, thus Zn influences electron transfer reactions including those of the Krebs cycle and hence affecting the plant's energy production, also, zinc binding tightly to Zn-containing essential metabolites in vegetative tissues, such as in Zn-activated enzymes, e.g., carbonic anhydrase, which plays a role in photosynthesis, is localized in the cytoplasm and chloroplasts and may facilitate the transfer of CO /HCO G for photosynthetic CO fixation [10].

Applying growth regulators especially ascorbic acid can modify morphological and physiological characteristic of plant and may also induce better adaptation of plant to environment which improve the growth and yield. It plays a major role in cell division and

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cell differentiation and affect many other physiological and developmental processes in plants including apical dominance, nutrient mobilization, chloroplast development, senescence and improve yield and chemical constituents of many crops and increasing the photosynthetic pigments content [11]. Therefore, this investigation was undertaken to evaluate the efficiency of foliar application of zinc, potassium or ascorbic acid to reduce the harmful effect of salt stress on biomass production, biochemical composition and salt tolerance of *Kochia indica* plants, and develop a management technique for productive use of halophytes grown in saline habitats.

2. Materials and Methods

Two field experiments were carried out at a private farm around Qaroon lake, Fayum Governorate at the two successive summer seasons of 2011 - 2012 to study the effect of foliar application of zinc (300 ppm Zn-EDTA), potassium (2.0% KNO_3) or ascorbic acid (200 ppm) in addition to fresh water as control on vegetative growth and some physiochemical parameters of (*Kochia indica* L) grown under diluted saline water irrigation (Fresh water, 25% and 50% of Lake water), analysis of irrigation water are presented in table (1).Seeds of Kochia were sown at 17th and 19th May in 2011-2012 seasons respectively.

Table 1: Chemical analysis of diluted saline water irrigation of Qaroon Lake (Average data of 2011 and 2012 seasons)

Characters	Fresh water	25%	50%
pH	7.69	8.13	8.42
EC (ds/m)	0.75	13.69	25.87
Na (mg/L)	55.39	3265.36	6752.14
K (mg/L)	2.15	85.36	152.36
Cl (mg/L)	128.36	4236.12	8256.26
Ca (mg/L)	85.36	112.03	131.88
Mg (mg/L)	10.36	52.45	113.56

Experiment was laid out in split plot design with three replicates (4×3 m distance between plants) i.e. 350 trees/fed., Saline irrigation treatments were in the main plots and foliar treatments were in the sub-plots. Drip irrigation was carried out every two days with the specified treatment by mixing Lake water with fresh water in one cubic meter plastic tanks

The initial physical and chemical characteristics of the soil were determined according to [12], are shown in Table 2. Nitrogen was applied in the form of ammonium sulphate (20.5% N) at the rate of 200 g/plant Phosphorus fertilizers in the form of calcium super phosphate (37% P2O5) 200 g/plant and potassium as potassium sulphate (48% K2O) , 75 g / tree. All agronomic practices were followed as recommended for Kochia production in this district.

A representative vegetative plant sample was taken after 210 days from sowing for each treatment from four replicates for measuring plant height (cm), number of branched/plant, leaf area (cm2), shoot dry weight (g), root dry weight (g) and shoot/root ratio. Salt tolerance index was calculated as total plant dry weight obtained from different seawater concentration compared to total plant dry weight obtained from plants irrigated with fresh water, STI=[(TDW at Sx/TDW at S1)x100], whereas STI=salt tolerance index, TDW=total dry weight, S1=control treatment, Sx= x treatment (Seydi *et al.*, 2003) [13]. The following physiochemical measurements were determined in the fresh leaves: chlorophyll a+b (mg/g fresh weight) according to Von Wettstein (1957) [14], proline (μg/g) according to Bates *et al.*,(1979) [15], osmotic potential were obtained from the corresponding values of cell sap concentration tables given by Gusev (1960) [16]. Then the harvested shoots were dried to constant weight at 70 C° to determined values of succulence (ratio of fresh weight/dry weight) according to Tiku (1979) [17], total nitrogen percentage according to A.O.A.C. (1975) [18] and the crude protein content was calculated by multiplying total nitrogen concentration by 6.25. Soluble carbohydrates content determined by the method described by Dubois *et al*., (1956) [19]. The contents of potassium were determined in the digested material using Jenway flame photometer as described by Williams and Twine (1960) [20]. Zinc was determined by the method described by A.O.A.C. (1975) [18]. The obtained results were subjected to statistical analysis of variance according to Snedecor and Cochran (1982) [21] and the combined analysis of the two seasons was calculated according to the method of [22].

Table 2: Soil mechanical and chemical analyses of the experimental sites (Average data of 2011 and 2012 seasons)

Soil Characters	Depth (cm)	
	0-30	30-60
EC (m mohs/cm)	14.32	8.71
HCO3%	13.11	12.22
SO4%	99.65	68.57
Cl%	198.36	175.65
Ca (ppm)	78.12	75.91
Mg (ppm)	27.55	25.36
K (ppm)	1.78	1.71
Na (ppm)	287.69	235.69
pH	7.41	7.10
Organic C%	2.15	2.01
Sand (%)	22.12	23.01
Silt (%)	16.40	14..98
Clay (%)	61.48	62.01

3. Results and Discussion

3.1 Effect of saline irrigation on Kochia indica growth

Data presented in Fig (1) show that increasing saline water concentration in the irrigation water to 25% significantly increased plant height, number of branched/plant, leaf area, shoot dry weight and root dry weight compared to fresh water, while increasing seawater concentration in the irrigation water up to 50% significantly adversely affected the previous characters. Similar results were obtained by Tawfik *et al*., (2011) [23] Such stimulatory effect of moderate salinity on growth of some halophytic plants may be attributed to improved shoot osmotic status as a result of increased ions uptake metabolism (Naidoo *et al.*, 1995) [24]. On the other hand, the reduction in growth and yield under high salinity levels could be due to reduction in photosynthesis, disturbance in mineral uptake, protein synthesis or carbohydrate metabolism (Al-Garni, 2006) [25]. He added that in most halophytic species growth decreases gradually with the increase of salt rate in the culture medium above a critical threshold specific to each species. In addition, Ashour *et al*., (2004) [26] attributed the reduction in growth at higher salinity level to reduced turgor and high energy cost of massive salt secretion and osmoregulation. Similar results were obtained by Tawfik *et al.*, (2013) who reported that low NaCl concentrations stimulate growth of some halophytic species [4].

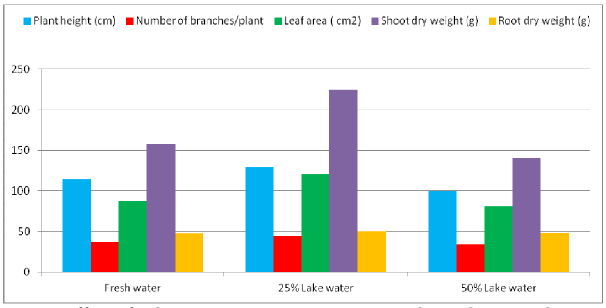

Fig 1: Effect of saline irrigation treatments on *Kochia indica* growth. (Combined analysis of 2011 and 2012 growing seasons). (LSD 5%) Plant height (cm): 6.21, Number of branches/plant: 3.31, Leaf area (cm^2): 6.24, Shoot dry weight: 9.99, Root dry weight (g): NS.

3.2 Effect of foliar treatments on on some growth parameter of Kochia indica.

Data presented in Fig (2) clarified that, all foliar spraying treatments significantly increased plant height, number of branched/plant, leaf area, shoot dry weight and root dry weight. Moreover, potassium significantly surpassed the other treatments. In this concern, Michael *et al.*, (2004) [27] attributed such enhancement effect of spraying plants with Zn and K on growth might be attributed to the favorable influence of these nutrients on metabolism and biological activity and its stimulating effect on photosynthetic pigments and enzyme activity which in turn encourage vegetative growth of plants. Moreover, Foyer *et al.*, (1994) [28] stated that, the stimulatory effect of ascorbic acid may be due to its substantial role in many metabolic and physiological processes. They added that antioxidant defense system, rather than a single antioxidant, is responsible for protection in stressed plant. Our results are in agreement with those obtained by Thalooth *et al.*,(2006) [29] and Khan *et al.*, (2006) [30] who stated that foliar application of potassium or zinc increased yield of plants.

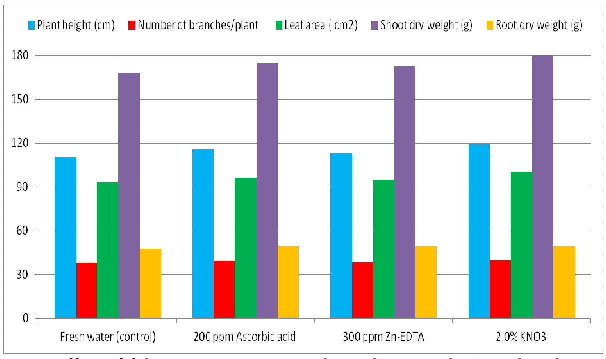

Fig 2: Effect of foliar treatments on *Kochia indica* growth. (Combined analysis of 2011 and 2012 growing seasons). (LSD 5%) Plant height (cm): 6.58, Number of branches/plant: NS, Leaf area (cm^2): 6.58, Shoot dry weight: 10.68, Root dry weight (g): NS.

3.3 Effect of interaction between saline irrigation and foliar treatments on Kochia indica growth.

Data in Fig (3) revealed that, the interaction between diluted saline irrigation water treatment and foliar spraying of the different nutrients significantly affected plant height, number of branched/plant, leaf area, shoot dry weight and root dry weight. However, foliar application of K recorded the highest values for all studied parameters under 25% dilution saline water concentration. On the other hand, the lowest values were recorded in (control treatment) sprayed with fresh water at the level of 50% Lake water irrigation. Similar results were obtained by Tawfik *et al*., (2008) [31]. These results coincide with those obtained by Khan *et al*., (2006) [30] who stated that, Ascorbic acid alleviated the salinity effects in some halophytic plants.

3.5 Effect of foliar treatments on biochemical composition and some physiological aspects.

As for the foliar spraying treatments Table (4) cleared that foliar spraying with either Ascorbic acid, Zn or K generally increased the content of chlorophyll a+b, crude protein, potassium and zinc as well as STI and succulence values as compared with control plants.

The previous treatments decrease the content of soluble carbohydrates, proline and osmotic potential values. These results are coincide with those obtained by Khan *et al.*, (2006) [30]. It is clear that foliar treatments improved all the tolerance feature of *Kochia indica* plants and increase plant adaptation to saline irrigation. These results coincide with the results obtained by Thalooth *et al.*,(2006) [29] and Abd El aziz *et al.*, (2006) [38] who sated that foliar application of either potassium or zink increased chlorophyll a+b, crude protein, potassium and zinc .

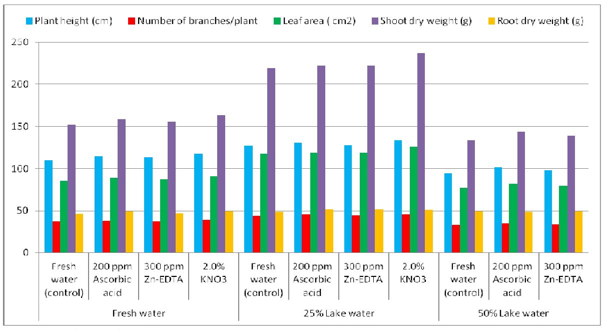

Fig 3: Effect of interaction between saline irrigation and foliar treatments on some *Kochia indica* growth (Combined analysis of 2011 and 2012 growing seasons). (LSD 5%) Plant height (cm): 13.65, Number of branches/plant: 5.36, Leaf area (cm2): 12.84, Shoot dry weight: 18.65, Root dry weight (g): NS.

3.4 Effect of saline irrigation treatments on some physiochemical parameter of Kochia indica.

Data presented in Table (3) show that raising irrigation salinity levels up to 50 % significantly increase the content of chlorophyll a+b , proline and soluble carbohydrates as well as succulence. On the other hand, the same treatment decreased succulence as well as the content of potassium and zinc. However moderate saline irrigation i.e. 25 % generally increased crude protein content. Regarding the effect of diluted seawater irrigation and foliar application on salt tolerance index (STI), It is evident that irrigating *K, idica* plants with high levels of saline water (50%) had the most deleterious effect on STI. In other words, the deleterious effect of salinity on productivity increased with increasing the level of salinity. Similar results were obtained by Tawfik *et al*., (2011)[31]. In this respect, Murphy *et al.*, (2003) [32] suggested that both proline and soluble carbohydrates act as compatible solutes under high salinity levels. Kusaka *et al.*, (2005) [33] added that, the observed increase in osmotic potential might be due to the accumulation of inorganic solutes, several organic components such as sucrose, glucose, quaternary ammonium compounds, and amino acids including proline. He *et al.,* (2005) [34] added that the accumulation of sodium ions inside the vacuoles generate more negative water potential that favors water uptake by the cell and better tissue water retention under high salinity levels. Similar results were obtained by Tawfik *et al.,* (2013) [4]. On the other hand, the depressing effect of salinity on potassium could be attributed to the difficulty of its uptake due to competition with the high concentration of sodium in the root medium. Lycoskoufis (2005) [35] stated that the inhibition of photosynthesis under high salinity levels predominantly due to reduced stomatal conductance. The stimulating effect of moderate salinity on protein accumulation of some halophytic plants may be due to the increased synthesis of certain new sorts of proteins (Dubey and Rani, 1989) [36]. On the other hand, the reduction in protein content under high salinity level may be due to the disturbance in nitrogen metabolism, inhibition of nitrate absorption or the decrease of the availability of amino acids and denaturation of the enzymes involved in amino acids and protein synthesis (Sher Mohamed *et al*., 1994) [37].

T able (3) Effect of saline irrigation treatments on some physiochemical parameter of *Kochia indica*. (Combined analysis of 2011 and 2012 growing seasons)

Saline irrigation treatment	**Crude protein content %**	**Chlorophyll a+b mg/g fresh wt.**	**Soluble carbohydrates %**	**Proline content (ppm)**	**Potassium content (mg/g dry wt.)**	**Zinc content (ppm)**	**Succulence**	**Osmotic potential**	**Salinity tolerance index (STI)**
Fresh water	8.41	6.07	31.72	281.55	13.77	37.73	3.75	6.85	103.65
25% Lake water	10.13	6.26	33.79	292.86	12.30	34.32	3.57	7.73	139.06
50% Lake water	8.16	6.32	35.64	376.17	11.66	30.67	3.30	8.28	95.88
LSD 5%	0.62	0.36	1.92	17.02	0.73	1.90	0.20	0.47	5.26

T able (4) Effect of foliar treatments on some physiochemical parameter of *Kochia indica*. (Combined analysis of 2011 and 2012 growing seasons)

Foliar treatments	**Crude protein content %**	**Chlorophyll a+b mg/g fresh wt.**	**Soluble carbohydrates %**	**Proline content (ppm)**	**Potassium content (mg/g dry wt.)**	**Zinc content (ppm)**	**Succulence**	**Osmotic potential**	**Salinity tolerance index (STI)**
Fresh water (control)	8.71	6.01	35.22	329.51	12.18	31.66	3.39	7.86	109.14
200 ppm Ascorbic acid	8.81	6.12	33.72	321.55	12.47	32.72	3.50	7.71	113.22
300 ppm Zn-EDTA	8.98	6.33	33.29	310.99	12.55	39.00	3.60	7.52	111.85
2.0% KNO_3	9.11	6.43	32.63	305.40	13.08	33.58	3.67	7.40	117.25
LSD 5%	0.72	0.39	23.96	19.79	0.80	2.03	0.22	0.50	5.64

3.6 Effect of interaction between diluted Lake water irrigation and foliar treatments on some physiochemical parameter of Kochia indica.

Table (5) show that the highest content of crude protein and photosynthetic pigments were recorded in *K indica* plants sprayed with 2% KNO3 and irrigated with 25% Lake water, meanwhile plants sprayed with 300 ppm Zn-EDTA and irrigated with fresh water produced the highest zinc content. Furthermore, plants sprayed with fresh water and irrigated with 50% seawater produced the highest content of soluble carbohydrates and proline as well as succulence and osmotic potential values. On the other hand, the treatment foliar potassium x fresh water gave the highest content of potassium and values of succulence. Similar results were obtained by Khan *et al*., (2006) [30], Thalooth *et al.*,(2006) [29] and Tawfik *et al*., (2008) [31] who found that, foliar application of nutrients has been reported to improve the crude protein content and counteract the effects of salt stress.

5. Conclusion

Kochia indica irrigated with seawater represent a considerable potential as crop plants. Their growth may be stimulated by the presence of salts in the growth medium. At high salinity their growth is presumably limited by many factors but mainly because an imbalance in nutrient uptake. Increased research on the selection of halophytic species which have an economic utilization may enable the rehabilitation and revegetation of salt-affected lands given that the appropriate soil and irrigation management is applied. Foliar application with potassium, zinc or ascorbic acid positively affected all the growth and physiological criteria as well as salt tolerance of the tested plants compared with unsprayed plants (control). Foliar application with potassium surpasses the other treatment especially at high levels of saline irrigation. However, additional research to identify the agronomic treatment for these plant species is important in developing strategies for their use.

T able (5) Effect of interaction between saline irrigation and foliar treatments on some physiochemical parameter of *Kochia indica*.(Combined analysis of 2011 and 2012 growing seasons)

Saline irrigation treatment	Foliar treatments	Crude protein content %	Chlorophyll a+b mg/g fresh wt.	Soluble carbohydrates %	Proline content (ppm)	Potassium content (mg/g dry wt.)	Zinc content (ppm)	Succulence	Osmotic potential	Salinity tolerance index (STI)
Fresh water	Fresh water (control)	8.23	5.79	32.13	291.51	13.25	34.97	3.53	7.08	100.00
	200 ppm Ascorbic acid	8.35	6.00	31.83	286.50	13.56	36.19	3.75	6.90	104.89
	300 ppm Zn-EDTA	8.45	6.14	31.61	275.74	13.67	42.62	3.82	6.76	102.62
	2.0% KNO_3	8.61	6.37	31.31	272.46	14.58	37.14	3.91	6.66	107.10
25% Lake water	Fresh water (control)	9.88	6.03	35.69	310.40	12.08	31.86	3.49	7.96	134.95
	200 ppm Ascorbic acid	10.02	6.14	33.65	294.21	12.22	32.84	3.51	7.87	137.90
	300 ppm Zn-EDTA	10.25	6.40	33.25	286.79	12.24	38.88	3.59	7.59	137.95
	2.0% KNO_3	10.36	6.47	32.58	280.04	12.65	33.69	3.69	7.51	145.45
50% Lake water	Fresh water (control)	8.02	6.19	37.85	386.62	11.22	28.16	3.14	8.52	92.46
	200 ppm Ascorbic acid	8.05	6.21	35.69	383.95	11.64	29.12	3.25	8.36	96.88
	300 ppm Zn-EDTA	8.23	6.44	35.01	370.44	11.75	35.51	3.39	8.21	95.00
	2.0% KNO_3	8.35	6.46	34.00	363.69	12.02	29.90	3.41	8.02	99.19
LSD 5%		0.98	0.57	34.87	28.81	1.16	2.95	0.32	0.74	9.89

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