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Research Article
Biomass and Some Physiological Aspects of *Spartina patens* Grown under Salt Affected Environment in South Sinai

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Abstract
Background and Objective: Salinity is a serious agro-environmental problem which limiting plant growth and productivity especially in arid and semi-arid regions of the world. Most of the developing countries suffer from shortage of cultivated area and lack of water resources as well as increasing salinity of agricultural land as a result of climate changes. So growing non-traditional crops such as halophytic plants is a promising solution to solve problems of saline habitats. **Methodology:** For this concern, two field experiments were carried out during 2014 and 2015 seasons at the Model Farm of National Research Centre, El Tour, South Sinai to study the impact of organic fertilization with farmyard manure (5 t fed^{-1}), chicken manure (5 t fed^{-1}) and foliar application with KNO_3 (2%), Zn-EDTA (100 ppm) as well as their interaction on biomass production, biochemical composition of *Spartina patens*. **Results:** Organic treatment (chicken manure 5 t fed^{-1}) significantly increase the fresh weight of different cuttings, total productivity, chlorophyll a+b, crude protein, potassium content and K/Na ratio compared with control treatment or with farmyard manure. On the other hand, organic treatment (Farmyard manure or chicken manure) decreased the contents of soluble carbohydrates, sodium, calcium and proline as well as succulence, osmotic potential values and Ca/Na ratio. Foliar spraying with KNO_3 significantly increase fresh weight of different cuttings, total productivity, chlorophyll a+b, crude protein, potassium content and K/Na ratio compared with tap water or Zn-EDTA. Meanwhile foliar spray with tap water significantly increase the contents of soluble carbohydrates percentage, sodium, calcium and proline as well as the values of succulence, osmotic potential and Ca/Na ratio. As for the interaction effect between organic treatment and foliar treatment, data show that, the highest values of fresh weight cuttings, total productivity, chlorophyll a+b, crude protein percentage, potassium content and K/Na ratio were recorded in plants fertilized with chicken manure (5 t fed^{-1}) and sprayed with 2% KNO_3. Furthermore, plants sprayed with tap water without organic manure produced the highest content soluble carbohydrates percentage, sodium, calcium and proline as well as succulence and osmotic potential. **Conclusion:** It can be recommended the applications of both organic fertilizer (5 t fed^{-1}) and foliar spray with K^+ and Zn-EDTA under saline sandy soil conditions.

Key words: *Spartina patens*, soil salinity, organic fertilizer, foliar application of K and Zn, growth, yield

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

INTRODUCTION

One of the most important economic problems that world face at the moment in many developing countries is the problem of desertification and loss of cultivated land due to climate change and lack of water resources and high rate of evaporation in arid and semi-arid regions due to rising temperature of the earth as well as rising salinity in the of soil and ground water. Salinity reduces plant growth by inhibiting many physiological and biochemical processes such as nutrient uptake and assimilation[1,2].

So cultivation of plants appropriate for this kind of habitats is a vital solution. Halophytes plants are able to survive and complete their life cycle under condition of saline soil[3,4]. Halophytes have the ability to solve the problem of salinity and also take advantage of the abandoned salt affected soils.

Spartina patens is considered an alternative forage crop, having good nutritional values. Several study reported that halophytic plants can grow successfully in salt-affected soil[5,6]. The ecosystem and human life have become under intense threat due to overdependence on chemical fertilizers. Gradual, consistent and systematic depletion of soil micro-flora and fauna, as well as increase in leaching and soil erosion are some of the problems of overdependence on chemical fertilizer. Hence, the renewed interest in proper and effective use of organic manure to maintain soil fertility[7]. Application of manure is the key to soil fertility because it has rich content of nitrogen, phosphorus, potassium and many other nutrients which increase productivity of the soil[8]. Moreover, organic matter improves physical and chemical conditions of the soil by serving as a storehouse or supply for plant nutrient element and by the positive impact of microorganisms which increase fertility of the soil[4]. Organic manure also helps to improve the physical condition of the soil and provides the required plant nutrients. It enhances cation exchange capacity and acts as a buffering agent against undesirable soil pH fluctuations[9]. The application of organic manure has been found to have higher comparative economic advantage over the use of inorganic fertilizer[10].

Potassium is a vital plant nutrient that has a principle role in plant growth and development. It plays very important role in photosynthesis process, enzyme activity, protein synthesis, carbohydrates and fats, translocation of photosynthetic, enabling their ability to resist pests and diseases. Also, potassium is considered as a major osmotically active cation in plant cell[11] where it enhances water uptake and root permeability and acts as a guard cell controller, beside its role in increasing water use efficiency[12]. Furthermore, Mahmood[13] has shown that foliar feeding with potassium mitigates the unfavorable impacts of salinity through its role in stomatal regulation, osmoregulation, energy status, charge balance, protein synthesis and homeostasis.

Zinc is one of the most essential micronutrient elements for the perfect and healthy growth and development of plants. It affects protein synthesis process in plants hence is considered to be the most critical micronutrient[14]. The Zn is also crucial in taking part in plant development due to its catalytic action in metabolism for all plant species[15], whereas Zn is used by the plant in many of its vital processes such as synthesis of protein, structure and functions of membrane, expression of genes and oxidative stress[16]. Furthermore, zinc is an essential micronutrient that affects several metabolic processes of plants[17]. They added that, the function of zinc is to help a plant to produce chlorophyll. One of the proper methods of micronutrients application for better uptake and utilization is foliar spray of micronutrients, since foliar fertilization accounts on supplying small amounts of nutrients directed to the leaves, lower cost, ease of application, good quality of fertilizers used and fertilizers readily soluble in water[18].

Thus, this study aims to determine the effect of organic fertilization and foliar application of K^+ and Zn-EDTA on *Spartina patens* in saline habitats.

MATERIALS AND METHODS

Tow field experiments were carried out at the Model Farm of National Research Centre, El Tour, South Sinai to study the impact of organic fertilization with Farmyard manure (5 t fed^{-1}), chicken manure (5 t fed^{-1}), foliar application with KNO_3 (2%) and Zn-EDTA (100 ppm) as well as their interaction on biomass production, biochemical composition of *Spartina patens* plants and transplanted at 6th March, 2014 and 15th March, 2015 with 30 cm between plants and 75 cm between rows, plants grown under drip irrigation system with saline water (EC 8.7 dS m^{-1}), water analysis of Abo Kalam Well are presented in Table 1.

Table 1: Water analysis of Abo Kalam well, El Tour, South Sinai

pH		7.49
EC (dS m^{-1})		8.70
Soluble cations (mEq L^{-1})	K^+	0.50
	Na^+	69.20
	Mg^{2+}	11.90
	Ca^{2+}	21.60
Soluble anions (mEq L^{-1})	SO_4^{2-}	26.60
	Cl^-	74.20
	HCO_3^-	2.40
	CO_3^{2-}	-

Table 2: Mechanical and chemical analysis of the soil

Depth		0-30 (cm)	30-60 (cm)
Soil texture		Sandy	Sandy
pH		8.1	8.40
EC (dS m^{-1})		15.1	4.52
Soluble cations (mEq L^{-1})	K^+	0.4	0.24
	Na^+	112.0	27.00
	Mg^{2+}	28.8	5.50
	Ca^{2+}	60.5	12.50
Soluble anions (mEq L^{-1})	SO_4^{2-}	61.0	10.64
	Cl^-	139.0	31.00
	HCO_3^-	2.7	3.60
	CO_3^{2-}	-	-

Table 3: Chemical composition of farmyard manure and chicken manure

Characters	Farmyard manure	Chicken manure
Organic matter (%)	49.2	32.65
Organic carbon (%)	29.0	21.36
C/N ratio	14.7	14.10
pH	7.5	7.20
EC (dS m^{-1})	2.2	1.65
Total N (%)	2.0	1.12
P (ppm)	116.0	85.00
K (ppm)	105.0	66.00

Mechanical and chemical analyses of the soil was carried out by using the standard method described by Klute[19] (Table 2). Each experiment included 9 treatments, which were the combinations of three organic fertilization treatments (chicken manure 5 t fed^{-1}, farmyard manure 5 t fed^{-1} in addition to control treatment) and three foliar application treatments (100 ppm Zn-EDTA, 2.0% KNO_3 in addition to tap water as control treatment). Organic treatments occupied the main plots, whereas foliar application treatments occupied the sub plots in split plot design with three replicates. Chemical composition of farmyard manures and chicken manure are presented in Table 3.

Four equal doses of calcium superphosphate (15.5% P_2O_5), potassium sulphate (48.0% K_2O) and urea (46.5% N) at the rate of 19 kg P_2O_5 ha^{-1}, 14 kg K_2O ha^{-1}, 62 kg N ha^{-1}, respectively were added after each cutting. Foliar application was carried out 5 days after each cutting. Cuttings were taken at 2 months intervals.

The following physiochemical measurements were determined in the fresh harvested shoot of the second cutting each year: chlorophyll a+b (mg g^{-1} fresh weight) according to Von Wettstein[20], proline (µg g^{-1}) according to Bates *et al.*[21], osmotic potential were obtained from the corresponding values of cell sap concentration tables given by Gusev[22]. Then the harvested shoots were dried to constant weight at 70°C to determine values of succulence (ratio of fresh weight/dry weight) according to Tiku[23], total nitrogen percentage according to AOAC[24] 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.*[25]. The contents of sodium and potassium were determined in the digested material using Jenway flame photometer as described by Eppendrof and Hing[26]. While, calcium was determined by Versinte method according to Jackson[27]. The K/Na and Ca/Na ratio were also calculated for each treatment. The obtained data were subjected to the analysis of variance according to Gomez and Gomez[28]. Since the trends were similar in both seasons, the homogeneity test was carried out according to Bartlett's test and the combined analysis of the data was applied according to Gomez and Gomez[28]. Treatment means were compared using LSD test at 5% level.

RESULTS AND DISCUSSION

Effect of organic manure treatments and foliar application with KNO_3 and Zn-EDTA on fresh weight cuttings and total productivity of *Spartina patens*: Results indicated significant differences amongst treatments in fresh weight of different cuttings Table 4. Addition of organic fertilizer had a positive impact on fresh weight of different cuttings and total productivity (kg m^{-2}) compared with control treatment (without organic fertilizers) with superiority to chicken manures over farmyard manure. Similar results were obtained by Bakhoum *et al.*[29]. In this concern, Tawfik *et al.*[30] reported that low NaCl concentrations stimulate biomass productivity of *Sporobolus virginicus*. This increase in fresh weight could be to the positive impact of manures which increased nutrients and improve soil properties, water holding capacity and increase biomass of microorganisms[31]. Moreover, the increase in the total yield resulting from application of manure may be attributed to the presence of readily available form of nutrients[32] and also to its ability to enhanced soil aggregation, soil aeration and water holding capacity, offers good environmental conditions for the root system of broccoli plants[33].

The same Table 4 also show that foliar application of either KNO_3 (2%) or Zn-EDTA (100 ppm) increased fresh weight of different cuttings as well as total productivity (kg m^{-2}) as compared with control treatment (tap water) with superiority to KNO_3 over Zn-EDTA. Similar results were obtained by Rezk *et al.*[34]. This could be due to that potassium has direct effect on the physiological processes of plant growth and played a key role in the stomatal opening of plants under stress conditions[13]. This increase may be due to the effect of potassium on enzyme and biological activities which induced nutrients content, vegetative growth and yield

Table 4: Effect of organic treatments and foliar application with KNO_3 and Zn-EDTA on fresh weight cuttings and total productivity of *Spartina patens* (Combined analysis of 2014 and 2015 seasons)

Treatments	1st cuttings (kg m^{-2})	2nd cuttings (kg m^{-2})	3rd cuttings (kg m^{-2})	4th cuttings (kg m^{-2})	Total productivity (kg m^{-2})
Organic manure treatments					
Control	1.76	2.01	2.38	2.01	8.16
Farmyard manure	2.07	2.57	2.77	2.47	9.85
Chicken manure	2.35	2.62	2.82	2.55	10.34
LSD 5%	0.13	0.15	0.17	0.12	0.65
Foliar application treatments					
Tap water	1.87	2.16	2.45	2.11	8.59
Zn-EDTA	2.05	2.40	2.70	2.38	9.53
KNO_3	2.27	2.65	2.82	2.53	10.27
LSD 5%	0.12	0.13	NS	NS	0.61

Table 5: Interaction effect of organic treatments and foliar application with KNO_3 and Zn-EDTA on fresh weight cuttings and total productivity of *Spartina patens* (Combined analysis of 2014 and 2015 seasons)

Organic manure treatments	Foliar application treatments	1st cuttings (kg m^{-2})	2nd cuttings (kg m^{-2})	3rd cuttings (kg m^{-2})	4th cuttings (kg m^{-2})	Total productivity (kg m^{-2})
Control	Tap water	1.56	1.88	2.23	1.75	7.42
	Zn-EDTA	1.75	1.98	2.35	2.03	8.11
	KNO_3	1.98	2.18	2.56	2.24	8.96
Farmyard manure	Tap water	1.94	2.25	2.55	2.25	8.99
	Zn-EDTA	2.03	2.68	2.86	2.52	10.09
	KNO_3	2.25	2.78	2.89	2.64	10.56
Chicken manure	Tap water	2.12	2.35	2.56	2.34	9.37
	Zn-EDTA	2.36	2.54	2.89	2.60	10.39
	KNO_3	2.58	2.98	3.02	2.71	11.29
LSD 5%		0.20	0.22	0.27	0.21	1.01

of plants[35]. They added that plants grown at higher K^+ level had better development of nodules and consequently higher nitrogen fixation. Furthermore, potassium has important role in water use efficiency and improves in growth plant condition and cell division and make of hydrocarbon, protein and quick transportation toward grain[36].

Interaction effect of organic manure treatments and foliar application with KNO_3 and Zn-EDTA on fresh weight cuttings and total productivity of *Spartina patens*: Data in Table 5 showed that the highest values for all cuttings (kg m^{-2}) and total productivity (kg m^{-2}) were recorded in plants treated with chicken manure (5 t fed^{-1}) and sprayed with KNO_3 (2%). On the other hand, the least values were recorded in plants missed organic treatment and sprayed with tap water. Similar results were obtained by Webb *et al.*[31] and Rezk *et al.*[34]. In this concern, Diacono and Montemurro[37] stated that, organic substances, such as farmyard manures, animal manures and composts can be used as amendments to increase and sustain the overall soil fertility. The same amendments could likely be considered for soil remediation in the salt-affected areas due to their high content of organic matter. This organic matter has several positive impacts on agricultural production, such as the slow release of nutrients, improvement of soil structure and the protection of soils against erosion[38].

Effectof organic manure treatments and foliar application with KNO_3 and Zn-EDTA on some physiological aspects of *Spartina patens*: Data in Table 6 clear that all treatments significantly affected all the studied characters as compared with control treatment. It is also clear from the table that the highest values for chlorophyll a+b and crude protein were recorded in plants fertilized with chicken manure as compared with the other treatments. On the other hand, the highest values for soluble carbohydrates, proline, succulence and osmotic potential were recorded in control treatment. Similar results were obtained by El-Tantawy *et al.*[33]. This positive effect of organic fertilizers on chlorophyll a+b could be due to enhancement of photochemical efficiency of leaf since organic fertilizers alleviate salt stress with maintenance of cell form through improving permeability of plasma membranes due to the increase of antioxidative enzymes[39].

Table 6 also shows the effect of foliar application treatments with KNO_3 (2%) and Zn-EDTA (100 ppm) on some physiological aspects of *Spartina patens*. It is clear that all treatment significantly affected all the studied characters as compared with control treatment. The highest values for chlorophyll a+b and crude protein were recorded in plants sprayed with K^+ as compared with the other treatments. On the other hand, the highest values for soluble carbohydrates, proline, succulence and osmotic potential were recorded in control treatment (tap water). Similar results were obtained by Hussein *et al.*[40]. In this concern, Abd El-Aziz *et al.*[41] stated that foliar application of either potassium or zinc increased chlorophyll a+b, crude protein. In this regards, Youssef[42] suggested that, under high salt stress plant cells decrease their osmotic potential by accumulation of some solutes such as proline and soluble sugars[43]. Found that, foliar application of nutrients has been reported to improve the crude protein content and counteract the effects of salt stress. Thalooth *et al.*[44] sated that foliar application of potassium increased chlorophyll a+b, crude protein and potassium.

Interaction effect of organic manure treatments and foliar application with KNO_3 or Zn-EDTA on some physiological aspects of *Spartina patens*: Data in Table 7 clear that all treatments significantly affected all the studied characters as compared with control treatment. The highest values for chlorophyll a+b and crude protein were recorded in plants fertilized with chicken manure (5 t fed^{-1}) and sprayed with KNO_3. On the other hand, the highest values for soluble carbohydrates, proline, succulence and osmotic potential were recorded in plants that did not receive organic fertilizer and sprayed with tap water. Similar results were obtained by Zaki *et al.*[45] and El-Tantawy *et al.*[33]. In this regards, Akanni and Ojeniyi[9] proved that, organic manure improve the physical condition of the soil and provides the required plant nutrients. It enhances cation exchange capacity and acts as a buffering agent against undesirable soil pH fluctuations.

Effect of organic manure treatments and foliar application with KNO_3 or Zn-EDTA on some nutrients content in *Spartina patens*: Data in Fig. 1 and 2 cleared that addition of either farmyard manure or chicken manure significantly increased

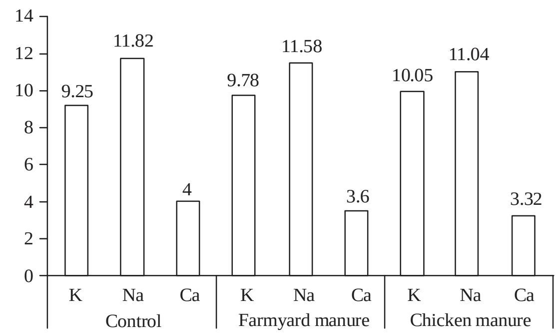

Fig. 1: Effect of organic manure treatments on K^+, Na^+ and Ca^{2+} (mg g^{-1} dry weight) contents of *Spartina patens*

Table 6: Effect of organic manure treatments and foliar application with KNO_3 and Zn-EDTA on some physiological aspects of *Spartina patens* (Combined analysis of 2014 and 2015 seasons)

Treatments	Chlorophyll a+b (mg g^{-1} dry weight)	Soluble carbohydrates (%)	Crude protein (%)	Proline (µg g^{-1} dry weight)	Succulence (fresh weight/dry weight)	Osmotic potential
Organic manure treatments						
Control	2.47	46.20	8.40	367.98	3.14	8.20
Farmyard manure	3.03	45.01	8.88	349.76	2.94	7.43
Chicken manure	3.16	43.65	9.43	341.73	2.67	7.15
LSD 5%	0.16	NS	0.53	21.25	0.17	0.47
Foliar application treatments						
Tap water	2.72	46.99	8.53	368.41	3.02	8.14
Zn-EDTA	2.88	45.19	8.89	357.18	2.95	7.46
KNO3	3.05	42.68	9.29	333.87	2.78	7.18
LSD 5%	NS	2.75	0.49	19.24	NS	0.41

Table 7: Interaction effect between organic manure treatments and foliar application with KNO_3 and Zn-EDTA on some physiological aspects of *Spartina patens* (Combined analysis of 2014 and 2015 seasons)

Organic treatments	Foliar application	Chlorophyll a+b (mg g^{-1} dry weight)	Soluble carbohydrates (%)	Crude protein (%)	Proline (µg g^{-1} dry weight)	Succulence (fresh weight/dry weight)	Osmotic potential
Control	Tap water	2.33	48.36	7.88	385.32	3.21	8.84
	Zn-EDTA	2.45	46.58	8.35	374.36	3.12	8.12
	KNO_3	2.62	43.65	8.98	344.26	3.08	7.65
Farmyard manure	Tap water	2.88	47.31	8.55	361.58	3.01	8.02
	Zn-EDTA	3.02	45.36	8.97	354.32	2.98	7.25
	KNO_3	3.19	42.36	9.12	333.38	2.84	7.02
Chicken manure	Tap water	2.95	45.30	9.15	358.34	2.85	7.55
	Zn-EDTA	3.18	43.62	9.35	342.87	2.74	7.01
	KNO_3	3.34	42.02	9.78	323.98	2.41	6.88
LSD 5%		0.25	4.32	0.84	32.54	0.28	0.65

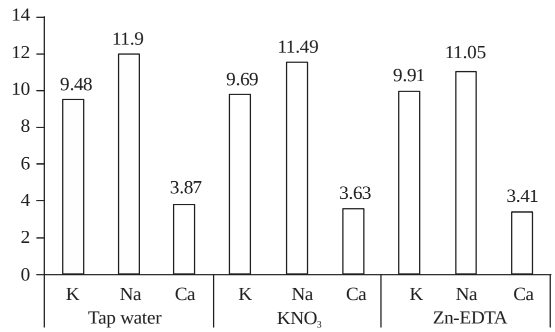

Fig. 2: Effect of foliar application with KNO_3 and Zn-EDTA on K^+, Na^+ and Ca^{2+} (mg g^{-1} dry weight) contents of *Spartina patens*

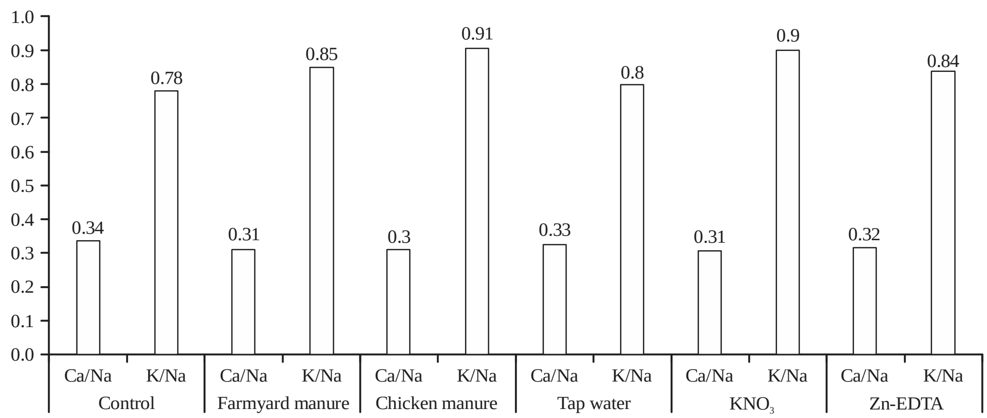

Fig. 3: Effect of organic manure treatments and foliar application with KNO_3 and Zn-EDTA on Ca/Na and K/Na ratio in *Spartina patens*

the content K^+ and Ca as well as K/Na ratio, while it decreases the content of Na^+ and Ca/Na ratio. These results are similar to those obtained by Abd El-Aziz *et al.*[41] and Tawfik *et al.*[6]. The role of organic fertilizers in increasing the content of some elements may be due to its positive impacts on stabilizing cellular membranes through increasing antioxidants substances, saving cell membranes from oxidative stress and hence improving plant cell permeability[46]. This increase was attributed to the positive effect of organic fertilizers on root growth, which consequently enhance the absorption of nutrients and alleviated the harmful effects of water stress[47].

Data in Fig. 2 and 3 also showed that foliar application with either KNO_3 or Zn-EDTA significantly affected the nutrients content of *Spartina patens* plants. However, these treatments positively affected K^+ content and K/Na ratio. These results coincide with those obtained by Tawfik *et al.*[5]. On this regards, Hajiboland and Joudmand[48] mentioned that, the selective uptake of K^+ as opposed to Na^+ is considered one of the important physiological mechanisms contributing to salt tolerance in many plant species. Therefore, less Na^+ accumulation and more K^+ content confirm tolerance of this plant species to salt stress. However, the salt tolerance in plants increased by increasing K^+ uptake which leads to increasing K/Na ratio in plant cells[49]. Moreover, potassium plays an important role in regulating osmotic potential, increasing water uptake ability[48]. High accumulation of sodium in plant tissues have been reported as one of the effective factors in reduction of photosynthetic pigments and rate of photosynthesis[1]. Potassium is an essential nutrient required in higher amounts for plant metabolism particularly photosynthesis and assimilates transport[50].

Interaction effect of organic manure treatments and foliar application with KNO_3 and Zn-EDTA on some nutrients content in *Spartina patens*: Date presented in Fig. 4 and 5 show that the highest values of K^+ and K/Na were recorded in *Spartina patens* plants fertilized with chicken manure and sprayed with KNO_3. On the other hand, the highest values of Na^+, Ca^{2+} and Ca/Na were recorded in plants that did not

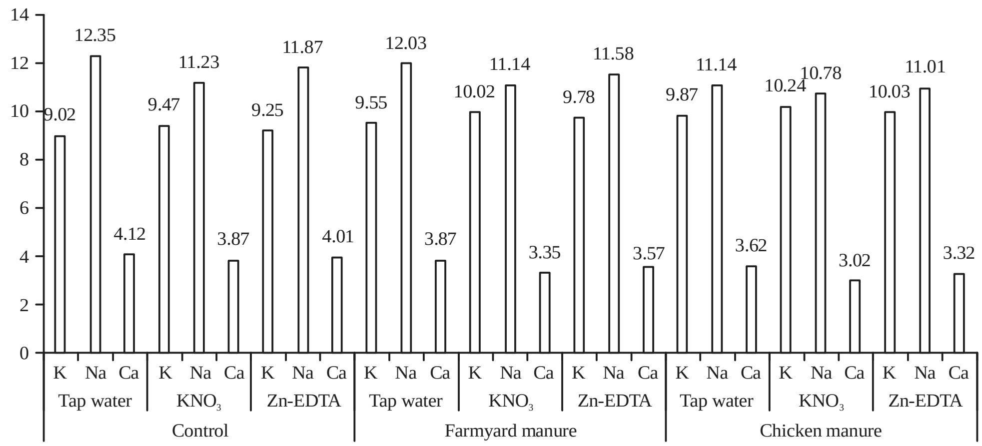

Fig. 4: Interaction effect of organic manure treatments and foliar application with KNO_3 and Zn-EDTA on K^+, Na^+ and Ca^{2+} (mg g^{-1} dry weight) contents of *Spartina patens*

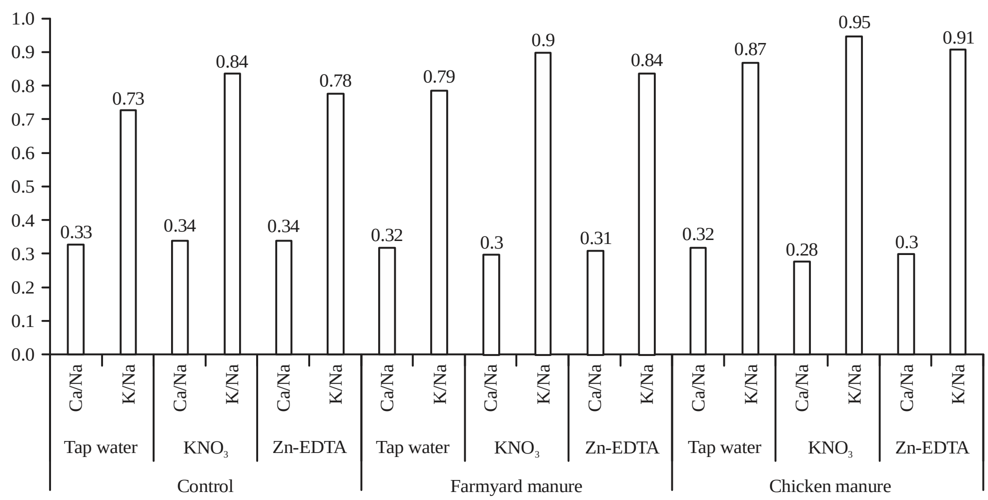

Fig. 5: Interaction effect of organic manure treatments and foliar application with KNO_3 and Zn-EDTA on Ca/Na and K/Na ratio in *Spartina patens*

receive organic fertilizers and sprayed with tap water. These results are in agree with those obtained by Tawfik *et al.*[43] and El-Tantawy *et al.*[33]. Moreover, K^+ is important to maintain the turgor pressure of plants under drought and salinity stress. In a recent study, a mixture of green waste compost, sedge peat and furfural residue (1:1:1 by volume) significantly reduced Na^+ and K^+ contents and improved CEC and the contents of available N, P and K[51].

CONCLUSION

In conclusion, this study proved the importance of application of organic fertilization especially in new reclaimed salt affected sandy soil. It is important to properly select organic materials, taking into consideration nutrients content, timing and method of application. As a matter of fact, organic fertilization in saline and sodic soils fulfils the sustainability of resources use, being able to recycle wastes locally stored, thus, contributing to solve the disposal problem of different agro-industrial wastes. This study also show the positive impact of both potassium and zinc as foliar application for improving yield and many agronomic, physiological and chemical traits of *Spartina patens* grown in salt affected sandy soil. Accordingly, it can be recommended the applications of both organic fertilizer (5 t fed^{-1}) and foliar spray with K^+ and Zn-EDTA under saline sandy soil conditions.

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