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Sustainable Cultivation of Some Promisinghalophytes in Desert Regions at South Sinai, Egypt

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Abstract: Sinai Peninsulais considered one of the main development pillars at the national level of Egypt. The ecosystem of Sinai is considered fragile where water resources are slightly poor (mainly saline ground water) in addition to low fertility salt affected soils. Because of the numerous environmental constraints, most of these areas have been neglected in the official development programs or have seen some attempts that failed because of the lack of adapted technologies to the local conditions and the socioeconomic context. The utilization of such desert in growing some suitable halophytic forage plants irrigated with saline water may contribute in sustainable use of these natural resources as a creative solution to attain environmental sustainability. These chosen species were primarily investigated in the green house. They have already been selected for their nutritional values and palatability by different animal as well as other beneficial purposes such as soil bioremediation, nonedible plants for biofuel production and finally for combating desertification. To accomplish this aim, an experimentwas conducted at the Model Farm of National Research Centre, El Tour, South Sinai, Egypt to evaluate the growth and productivity of some halophytic plant species to foliar application with different sources of potassium (KNO_3 (1 g/L), K_2SO_4 (1 g/L), KH_2PO_4 (1 g/L) and KCl (1 g/L in addition to tap water as control) on biomass production, chl. a+b and some physiological aspects as well as nutritional values of three halophytic plant species (*Atriplexhalimus*, *Suaedaaegyptiaca*and*Kochia scoparia*). Results showed that, these plants can grow well in such condition producing a reasonable biomass due to their tolerant features to these abiotic stress conditions. Foliar application with different potassium sources, significantly enhanced growth, biomass production and nutritional values of these halophytic plants with superiority to KNO_3 (1g/L).

Key words: Halophytes・Foliar potassium・Combating desertification・Biomass・Nutritional values

INTRODUCTION

With the continuous increase of the world population, continuous desertification of arable lands due to urbanization, global warming, low rainfall andincrease of soil salinity and aridity, the requirements for food, freshwater and fuel are bigger every day. This way an urgent necessity to develop, create and practice a new type of agriculture(saline agriculture), by using of low quality/saline water for irrigation, especially in regions experiencing water shortage [1]. Thus, there is an urgent need for finding abiotic tolerant plant species to survive under such stressful conditions. Since halophytic plants are already growing under such conditions and are adapted to these stresses, they are the most suitable candidates to be manipulated under these harsh arid conditions. Therefore, salt-tolerant plants provide a sensible alternative for many developing countries. These plants have the capacity to grow using land and water not valid for conventional crops producing food, fuel, fodder, fibber, essential oils and pharmaceutical products. In addition to their production capabilities they can be used simultaneously for soil rehabilitation [2].

Halophytes are a group of plants that can survive and reproduce in environments where the salt concentration is around 200 mM or more, whereas the

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non-halophytes, to which most of our crop plants belong, are sensitive to lower levels of salinity [3]. The key to survival under saline conditions is the ability and capacity of a plant to minimize the effect of sodium and other harmful ions by some physiological process[4].

*Atriplexhalimus*are among the most salt-tolerant higher plants. They have adapted to salinity by tolerating salts internally and/or by excreting salt [5]. Different studies have reported that low salinity levels do not have a deleterious effect on growth and that they may stimulate growth [6].*Suaedafruticosa* is a halophyte with potential for development as a cash crop and has the ability to remove salt from saline soil. It has optimal growth at 300 mMNaCl. Little is known about the molecular basis for salt tolerance in this plant. *Kochia scoparia* is a halophytic plant can be used for control of soil erosion [7].Undersander*et al*., (1990) [8] indicated that it is able to survive in a variety of harsh soil conditions, including sandy and alkaline soils. *Kochia scoparia* is drought, salinity and grasshopper tolerant and is able to grow in areas with very thin topsoil [7]. They added that, it is especially suited to arid to semi-arid regions.

One approach to minimize effects of salinity is use of nutrient foliar application to increase tolerance of plant salinity by alleviating Na^+ and Cl^- injury to plants [9].

The macronutrient potassium (K) plays an important role in stimulation of root growth, increasing leaf area, chlorophyll content, net assimilation rate, balancing membrane potential and turgor, activating enzymes, regulating osmotic pressure, stomatal movement and tropisms and reduction of the excess uptake and translocation of ions such as Na^+ and Cl^- [10]. The antagonistic effect of Na^+ (the predominant cation in salt affected soil) on uptake of K^+ is well established. Externally supplied K^+ may also increase endogenous K^+ content of seeds, required to tolerate salinity at germination [11] and ameliorate abiotic-stress effects [10]. An alternative solution to the salinity problem is to select plant species capable of utilizing sufficiently high concentrations of NaCl, edible for humans, and featuring high productivity, with glasswort (*Salicornia europaea* L.) being one of the most promising candidates to be included in the human diet [12].

The objectives of this study were to domesticate some salt tolerant halophytic plant species under foliar potassium application, for using in salt affected arid regions, where limited water supplies coupled with saline soils result in salinity and aridity stresses.

MATERIALS AND METHODS

A field experiment was conducted in Al Tour, South Sinai, Egypt, during the summer season of 2015 to evaluate the impact of foliar spraying with some sources of potassium[K_2SO_4 (1 g/L),KNO_3 (1 g/L), KH_2PO_4 (1 g/L) and KCl (1 g/L) in addition to tap water as control treatment]on biomass production(Kg fresh weight /fed), chlorophyll a+b content and some physiological aspects as well as nutritional values of three halophytic plant species (*Atriplexhalimus*, *Suaedafruticose* and *Kochia scoparia*) grown under drip irrigation system with saline water (EC : 8.7 dSm^{-1}), water analysis of Abo Kalam Well are presented in Table (1). Plants were transplanted at 25thMay 2015. Experiment was laid out (1.5 x 0.5 m distance between plant) i.e. 5600 plants /feddan (1 feddan = 0.42 h) in CRBD with three replicates. Physical and chemical analysis of the soil site was carried out by using the standard method described by [13], Table (2). Each plant was fertilized with 50 g calcium superphosphate (15.5% P_2O_5) and 30 g potassium sulphate (48.0 % K_2O) and 60 g urea (46.5% N) mixed with 100 g green manures (compost). Foliar treatmentswere carried out twice, 30 days after sowing and one month later. Each plant was irrigated three times per week with drip irrigation system. Vegetative sample was taken after 150 days from transplanting. Three replicates were taken for each treatment to determine biomass production of the shoot system (Kg fresh weight /fed).Chlorophyll a+b in the leaves (mg/g fresh weight) according to [14],proline (µg/g) according to [15], osmotic pressurewas obtained from the corresponding values of cell sap concentration tables given [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 [17]. The dried plants were then thoroughly ground to fine powder andtotal nitrogen percentage was determined according to the method described by [18] using the improved kjeldahl method and the crude protein content was calculated by multiplying total nitrogen concentration by factor of 6.25. Soluble carbohydrates content was determined by the method described by [19]. The contents of sodium and potassium were determined in the digested material using Jenway flame photometer as described by [20]. K/Na ratio was also calculated for each treatment. Crude fiber (CF), ether extract (EE) and ash were determined by standard analytical methods after [22]. Nitrogen free extract (NFE)

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

pH		7.49
EC dS^{-1}		8.7
	K^+	0.5
	Na^+	69.2
	Mg^{++}	11.9
	Ca^{++}	21.6
	SO4--	26.6
	Cl-	74.2
	HCO3-	2.4
	CO--	-

Table 2: Physical and chemical analysis of the soil.

Depth		0 – 30 cm	30 – 60 cm
Soil texture		Sandy soil	Sandy soil
pH		8.1	8.4
EC dSm^{-1}		15.1	4.52
	K^+	0.4	0.24
	Na^+	112.0	27.0
	Mg^{++}	28.8	5.5
	Ca^{++}	60.5	12.5
	$SO4^{--}$	61.0	10.64
	Cl^-	139.0	31.0
	$HCO3^-$	2.7	3.6
	CO^{--}	-	-

was calculated by the following formula: NFE % = 100-(%CP + %CF + %EE + %ash). Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF)were determined as [21]. The obtained data were subjected to statistical analysis of variance described by [23].

RESULTS AND DISCUSSION

Effect of different sources of potassium on biomass production (Kg fresh weight /fed) of *Atriplexhalimus*, *Suaedaaegyptiaca* and *Kochia scoparia*: The results on the effect of foliar application of different sources of potassium on biomass production (Kg fresh weight /fed) are presented in Figure (1). The three plant species produced a reasonable biomass under the circumstances of salt affected environment andsignificantly increased with foliar application of different K sources. The relative effects of foliar K on biomass production seem to vary from species to another. However, biomass production of *Atriplexhalimus*wasthe highest amounted to6253.2kg fresh weight /fed.under foliar application with KNO_3.This was true for the other plant species, foliar application of KNO3 recorded the highest values of fresh biomass amounted to 5405.1 and 4295.9 in *Suaedaaegyptiaca* and *Kochia scoparia*respectively. On the other hand, it was obvious that control treatments recorded the lowest fresh biomass production in the three species. Similar results were obtained by [15].In this concern, Hussein *et al*., (2013) [24] stated that, two foliar applications of potassium mono phosphate (KMP), 21 and 35 days after planting, increased plant growth.The efficacy of foliar fertilization is higher than that of soil fertilizer application in these situations. The reasons for this are because foliar application of nutrients is in general helpful to satisfy plant requirement and has a high efficiency and also to the independence of root activity and soil water availability [25]. At early growth stages, foliar fertilization could increase P and K supplies at a time when the root system is not well developed [26]. Thus, foliar nutrient application under drought and salinity conditions may be able to exclude or include a water deficit or nutrient effect under short-term drought or salt stress.

Effect of Different Sources of Potassium on chl. a+b (mg/fresh wt.) of *Atriplexhalimus*, *Suaedaaegyptiaca* and *Kochia scoparia*: Data of the impact of different foliar treatments of potassium on chl. a+b (mg/fresh wt.) are

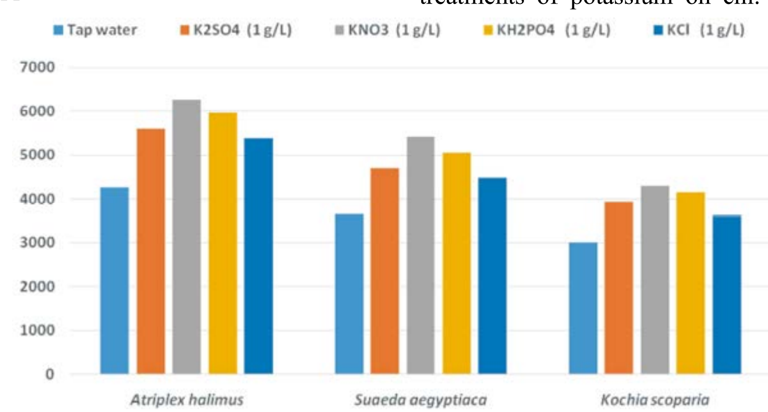

Fig. 1: Effect of different sources of potassium on biomass (Kg fresh weight /fed)of *Atriplexhalimus*, *Suaedaaegyptiaca* and *Kochia scoparia* (LSD 5% *A. halimus*= 378.68, LSD 5%*S. aegyptiaca* = 250.96 and LSD 5% *K. scoparia*= 223.23)

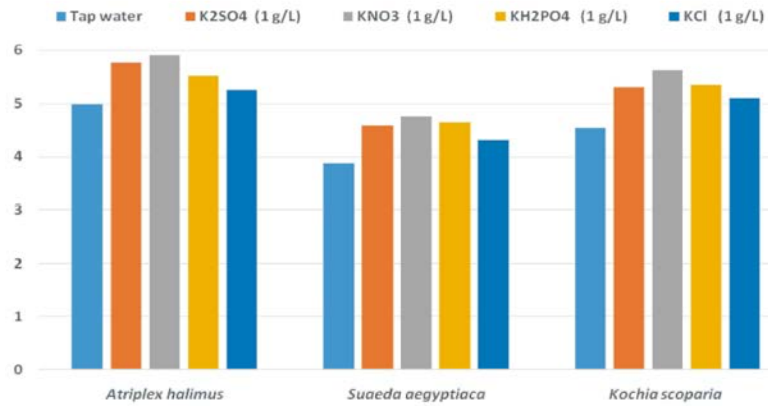

Fig. 2: Effect of different sources of potassium on chl. a+b (mg/fresh wt.) of *Atriplexhalimus*, *Suaedaaegyptiaca* and *Kochia scoparia* (LSD 5% *A. halimus*= 0.36, LSD 5% *S. aegyptiaca* = 0.29 and LSD 5% *K. scoparia*= 0.32)

presented in Fig (2). However, significant differences were obtainedfor the three plant species, foliar application of KNO3 recorded the highest content of chl. a+b. On the other hand, control treatmentrecordedthe lowest chl. a + b as compared with other treatment. In a descending order, from the highest values KNO_3 (1 g/L), KH_2PO_4 (1 g/L), K_2SO_4 (1 g/L), KCl (1 g/L) and finally tap water.In this concern, Zhao *et al*., [27] stated that, potassium deficiency promotes decrease in photosynthetic pigments such as chlorophylls, besides affect photosynthesis rate and chloroplast structure. The reduction in leaf chlorophyll content of the plants grown in NaCl stress has been attributed to the destruction of chlorophyll pigments and instability of the pigment protein complex [28]. Furthermore, increased salt content also interferes with protein synthesis and influences the structural component of chlorophyll [29]. Ramos *et al*., [9] mentioned that, K plays an essential role in enzymes water adjustment in plant tissues by potassium treatment activation, protein, energy transfer and phloem transport. Mengel and Kirkby [30] stated that, potassium is essential for many physiological processes, such as photosynthesis, translocation of photosynthates into sink organs, activation of enzymes and reducing excess uptake of ions such as Na and Fe in saline and flooded soils.

Effect of Different Sources of Potassium on Some Physiological Aspects of *Atriplexhalimus*, *Suaedaaegyptiaca* and *Kochia Scoparia*: Foliar spraying with potassium significantly affected all the studied physiological aspects of the three tested plant species (Table, 3). The highest content of K^+ as well as the values of K/Na were recorded in plants sprayed with 1% KNO_3. Regardless fertilization treatment, the highest values of K and K/Na was recorded in*Atriplexhalimus*. On the other hand, the highest values of osmotic potential values, prolinecontent µg/g dry wt., soluble carbohydrates%, succulence values and sodium content of the leaves mg/g dry weight were recorded in the control treatment (foliar spry with tap water).*Suaedaaegyptiaca* recorded the highest values of osmotic potential values, proline content µg/g dry wt., soluble carbohydrates%, while *Kochia scoparia* recorded the highest values of succulence values and sodium content of the leaves mg/g dry weight. Similar results were obtained by [31]. The beneficial effects of K^+ in improving salt tolerance of halophytic plants may be attributed to its enhancement effects on increasing plant metabolic activity due to its role on carbohydrate and N-metabolism, water absorption and transpiration in plant [9]. The positive action of fertilizer application with K might be related to its effect on water – plant relationship as well as metabolic and physiological activities of sugar beet plant [32] In this regard, Tawfik*et al*., [31] added that, foliar treatment with K significantly reduced the damaging action of salinity on plant growth and enhanced yield production of halophytic plants grown under saline conditions. Roghiehand Arshad [33] 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 (Table, 3) in the three plant, confirm tolerance of this plant species to salt stress. 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 [34]. Beneficial effect of higher osmolyte concentrations (such as potassium in this study) is reflected in maintenance of higher succulence values in tolerant varieties.

Table 3 Effect of different sources of potassium on some physiological aspects of *Atriplexhalimus,Suaedaaegyptiaca*and*Kochia scoparia*

Plant species	Foliar treatments	Osmotic pressure values (Atm)	Proline content µg/g dry wt.	Soluble carbohydrates%	Succulence	Sodium content of the leaves mg/g dry weight	Potassium content of the leaves mg/g dry weight	K / Na ratio
Atriplexhalimus	Tap water	7.88	356.43	40.48	3.61	17.76	11.35	0.64
	KNO_3 (1 g/L)	6.45	288.23	32.98	2.85	14.23	12.98	0.91
	K_2SO_4 (1 g/L)	6.55	291.15	33.08	2.95	14.51	12.19	0.84
	KH_2PO_4 (1 g/L)	6.88	296.36	33.69	3.01	14.78	12.29	0.83
	KCl (1 g/L)	7.36	344.41	39.09	3.49	17.15	12.19	0.71
Suaedaaegyptiaca	Tap water	9.81	393.97	44.86	4.31	19.69	8.66	0.44
	KNO_3 (1 g/L)	7.95	315.65	36.54	3.71	16.03	10.02	0.63
	K_2SO_4 (1 g/L)	8.01	327.39	37.27	3.80	16.37	9.21	0.56
	KH_2PO_4 (1 g/L)	8.11	343.91	39.11	3.93	17.18	9.61	0.56
	KCl (1 g/L)	9.31	367.94	41.92	4.10	18.40	9.31	0.51
Kochia scoparia	Tap water	8.91	372.85	42.42	5.13	19.62	9.51	0.48
	KNO_3 (1 g/L)	7.11	300.02	34.12	4.02	15.89	11.02	0.69
	K_2SO_4 (1 g/L)	7.28	304.36	34.63	4.19	16.22	10.23	0.63
	KH_2PO_4 (1 g/L)	7.41	308.17	35.06	4.24	16.42	10.65	0.65
	KCl (1 g/L)	8.61	353.82	40.27	4.87	18.72	10.03	0.54
LSD 5%	*A. halimus*	0.43	17.02	2.12	0.25	0.91	0.69	0.05
	S. aegyptiaca	0.41	16.36	2.02	0.22	0.87	0.66	0.04
	K. scoparia	0.39	16.03	2.01	0.21	0.83	0.62	0.04

Table 4: Effect of different sources of potassium on nutritional values of *Atriplexhalimus,Suaedaaegyptiaca*and*Kochia scoparia*

Plant species	Foliar treatments	CP	CF	Ash	ADF	NDF	EE	NFE
Atriplexhalimus	Tap water	10.88	23.12	25.47	23.51	16.52	3.02	37.51
	KNO_3 (3 g/L)	11.89	24.03	26.12	22.54	15.68	3.05	34.91
	K_2SO_4 (3 g/L)	12.58	24.36	26.35	22.12	15.62	3.12	33.59
	KH_2PO_4 (3 g/L)	12.25	23.89	25.99	22.84	16.12	2.99	34.88
	KCl (3 g/L)	11.55	23.55	25.84	23.09	16.33	3.14	35.92
Suaedaaegyptiaca	Tap water	7.85	18.23	23.24	20.01	14.02	2.35	48.33
	KNO_3 (3 g/L)	9.20	19.35	23.98	19.16	15.61	2.41	45.06
	K_2SO_4 (3 g/L)	9.53	19.55	24.13	18.98	15.42	2.39	44.40
	KH_2PO_4 (3 g/L)	9.31	18.92	23.78	19.32	15.85	2.42	45.57
	KCl (3 g/L)	8.62	18.86	23.55	19.55	16.03	2.40	46.57
Salicornia *europeae*	Tap water	9.25	25.02	27.26	24.25	16.28	2.34	36.13
	KNO_3 (3 g/L)	10.62	25.98	27.85	23.01	15.36	2.35	33.20
	K_2SO_4 (3 g/L)	10.98	26.23	28.01	22.87	15.03	2.40	32.38
	KH_2PO_4 (3 g/L)	10.78	25.64	27.62	23.55	15.84	2.38	33.58
	KCl (3 g/L)	10.13	25.36	27.55	23.87	16.01	2.40	34.56
LSD 5%	*A. halimus*	0.62	1.23	NS	1.21	0.91	NS	2.01
	S. aegyptiaca	0.45	1.05	NS	1.03	0.88	NS	2.66
	K. scoparia	0.51	1.28	NS	1.23	0.92	NS	1.98

Crude protein (CP), Crude fat (CF), Acid detergent fiber (ADF), Neutral detergent fiber (NDF), Ether extract (EE) and Nitrogen-free extract (NFE)

Potassium has a prevalent action in plants and is involved in maintenance of ionic balance in cell and bounds ionically to enzyme pyruvate kinase which is essential in respiration and carbohydrate metabolism [35]. However, the salt tolerance in plants increased by increasing K^+ uptake which leads to increasing K/ Na ratio in plant cells [36] Moreover, potassium plays an important role in regulating osmotic potential, increasing water uptake ability [33].Mengel and Kirkby (2001) [30] stated that, potassium is essential for activation of enzymes and reducing excess uptake of ions such as Na and Fe in saline and flooded soils. Wong *et al*., (2006) [37] stated that, sodium is not considered to be a plant nutrient, but it is essential for halophytes to accumulate salts to maintain turgor pressure and growth for survival in high salt.

Effect of Different Sources of Potassium on Nutritional Values of *Atriplexhalimus*, *suaedaaegyptiaca* and *kochia Scoparia*: Data regarding the nutritional values of *Atriplexhalimus*, *Suaedaaegyptiaca* and *Kochia scoparia* under different foliar treatments with potassium vary considerably in their nutritive value as indicated in Table (4). There were significant differences in the content of crude protein (CP), crude fiber (CF), Ash, ether extract (EE), nitrogen free extract (NFE), acid detergent fiber (ADF) and neutral detergent fiber (NDF) among different potassium treatments. It is clear from the data that, CP, CF and ash, significantly enhanced with foliar application of different sources of potassium with superiority to KNO_3. On the other hand, these treatments reduce the values of ADF, NDF andNFE of the three tested plant species. No clear effect for fertilization treatments on (EE) was detected. Similar results were obtained by [1].These plants attained a wide range of crude protein content (CP) varying from 7.85 % in *Suaedaaegyptiaca*sprayed with tap water (control) to 12.58 % in *Atriplexhalimus*sprayed with 1% KNO_3. These halophytic plants could be considered as good fodders because of their palatability for all animal species, in addition to their moderate content of protein. Meanwhile the highest values of CF amounted to 26.23 % was recorded in *Kochia scoparia* sprayed with 1% KNO_3. On the other hand, the highest values of ash amounted to 28.01was recorded in *Kochia scoparia* sprayed with KNO_3.

The highest values of acid detergent fiber **(**ADF) amounted to 24.25 % were recorded in *Kochia scoparia*, sprayed with tap water. ADF percentage is negatively relates to digestibility, ADF is used to calculate energy values. Low ADF forages are usually preferred.On the other hand, the highest values of NDF amounted to 16.52 % was recorded in *Atriplexhalimus*sprayed with tap water, NDF is one of the most valuable analysis to have conducted on forages for dairy rations. Low NDF is usually desired. The highest values of EE amounted to 3.12 in *Suaedaaegyptiaca*sprayed with $KNO_{3.}$ NFE recorded the highest value48.33 % in*Atriplexhalimus* sprayed with tap water. Similar results were obtained by [38] and [31]. Some of these plants have a considerable nutritive value which compete that of the traditional forage plants [39]. In this regards, the nutritive value of some halophytic shrubs (*Acacia saligna*, *Atreplexnummularia*, *A. semibaccata*, *A. halimus* and *Paspalumdistichum*) naturally grown in the Mediterranean coastal zone in Egypt was evaluated by [40]. A major aim is to evaluate the potential of local halophytes for wide economic use under the circumstance of El Tour, South Sinai Governorate, Egypt in the light of the progressive shortage of fresh water resources and soil salinization. Major research topics are to identify and select plant species tolerant to salt stress by selecting and using biomarkers to characterize halophytes, to evaluate the possible use of non-conventional water such saline water, to select halophytes of a potential importance in the field of human or animal nutrition [41]. He added that, recent advances in selecting species with high biomass and protein levels and the ability to survive a wide range of environmental conditions including salinity and water stress. In this concern, ICBA [42] stated that, at 20 dS/m, the fresh yield of *Atriplexlentiformis, Atriplexnummularia* and *Atriplexhalimus* reached nearly 25.0, 16.9 and 14.6 t/ha.

CONCLUSION

Overall, considering the results of this experiment, the following general conclusions can be drawn. *Atriplexhalimus*, *Suaedaaegyptiaca*and*Kochia scoparia*are true halophytic plant, very high tolerant to both salinity and drought stresses. These plant can grow well even under poor soil conditions (salt-affected desert soils) and drought (characteristics of the arid regions), they are suitable and beneficial plant species for cultivation under arid and semi-arid regions and shows a favorable growth and development with satisfactory soil surface coverage and yield under harsh desert environmental conditions due to its physiological features. Consequently, these species can be successfully used for restoration of the arid lands and for sustainable agriculture in arid regions as well as for combating desertification.

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