8th International Conference on Water Resources and Arid Environments (ICWRAE 8): 82-88
22-24 January 2019, *Riyadh, Saudi Arabia*

Domestication of Some Halophytic Plant Species in Salt Affected Soils and Water Salinity

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Abstract: In arid and Semi-arid regions improving agriculture is forced by the presence of fresh water and adequate. Soil health Under Egyptian condition, although agriculture is mainly depended on water derives from River Nile, many lands are suffered from both water and soil salinity. Adopting some halophytic species, which has some economic benefits is only the first options for improving such conditions. In arid and Semi-arid regions water scarcity is one of the major problems faced by many countries in arid regions worldwide.Egypt is an arid country where water shortage hampers land productivity.A field experiment was carried out in newly reclaimed sandy soil at private salt affected farm, in Manshiet El Gammal, Fayoum Governorate to study the impact of irrigation at different levels of water supplies at (100, 75 and 50% from full water irrigation requirement IR) on plant height, biomass production, leaves photosynthetic pigments content, crude protein content and some physiological aspects of two halophytic plant species (*Atriplex halimus* and *Leucaena leucocephala*) treated with two soil amendments viz., (charcoal 4 kg /plant and Hydrogel 20 g/ plant) compared to nontreated plants (control). Results showed that increasing water stress, significantly decreased plant height and fresh biomass as well as leaves chlorophyll content, however, *Atriplexhalimus* was less affected by water stress and contrary crude protein% was increased as compared to *Leucaena leucocephala*. Furthermore, protein content in plant tissues of Leucenaspecierecorded the highest value at was 50% of water stress.Finally, the present results are confirmed the fact, which stated that both plant species *Leucaena leucocephala* and *Atriplex halimus*beare highly drought-resistant when grown under water stress, additionally application of soil amendments could mitigate the harmful effect of water stress. The results indicated that these two plant species could produce economical biomass yields in arid environments, when irrigated at 75% soil moisture depletion. However addition of soil amendment reduces the negative impact of water stress on the studied characters and improve all the physiological aspects.

Key words: Atriplex halimus · Leucaena leucocephala · Water stress · Charcoal · Hydrogel

INTRODUCTION

Globally, the prediction of world population will doubled in the next 50 years, consequently water demand will increased, at least by the same rate, to cover the increments in food dements [1].

Therefore, the use of low-quality water for irrigation of some halophytic plant species will be a good co-excite under these circumstances. Since halophytic plants are characterized with the highly adaptability to water stress and has ability of well growing under harsh conditions. Also, under such condition these plant species may be the dominant option because of they are need minimum cultural practices, low financial investments and minimum inputs [2]. Among these, *Atriplex halmus* and *Leucaena leucocephala*, are a halophytic salt tolerant plant, is particularly well adapted to arid, semi-arid and salt-affected areas [3]. These plants characterized by high tolerance to drought and salinity. Moreover, they can provide a high quantity of leaf biomass during the critical time of growing season, being used as a forage rich in protein and carotene. Plants of the genus *Atriplex* are able to fix CO_2 following the C_4 biosynthetic pathway. These plants are characterized by highbiomass productivity, drought and salinity resistance and high efficiency in solar radiation use [4].

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Water saving techniques that increasing plant tolerability against unfavorable conditions and enhanced plant establishment and growth in soils has properties are required. One of these available technique is the use of super absorbent hydrophilic polymers [5]. Super absorbent polymers (SAPs) are substances that can hold large amount of water and nutrients when incorporated with soil and became available or slow released time by time as plants are required [6]. Whereas under non-water limiting conditions, they are reported to enhance nutrient uptake by plants, enhancing growth and may improve seedling growth and establishment through increasing soil holding capacity and regulating plant water supplies, particularly under arid environments [7]. Charcoal is the dark residue consisting of carbon and the remaining ash, obtained by removing water and other volatile constituents from vegetation substances [8]. The possible connections between biochar properties and the soil biota and their implications for soil processes have not yet been systematically described [9].

The objective of this work was to test the impact of addition of some soil amendment (Charcoal and hydrogel) on biomass production, photosynthetic pigments content, crude content as well as some physiological aspects of *Atriplex halmus* and *Leucaena leucocephala* grown under harsh conditions of soil and water salinity as well as water stress traits

MATERIALS AND METHODS

Field experiment was carried out in newly reclaimed sandy soil at private salt affected farm in Manshiet El Gammal, Fayoum Governorate to study the impact of water stress (100, 75 and 50% of irrigation water requirement IR) on plant height and biomass production, photosynthetic pigments content, crude protein content and some physiological aspects of two halophytic plant species (*Atriplex halimus* and *Leucaena leucocephala*) treated with some soil amendments (charcoal 4 kg /plant and Hydrogel 20 g/ plant as compared to conventional (without application control treatment).

Plants were transplanted at 25th Nov 2016. Experiment was laid out (1.5 x 2 m distance between plant) i.e. 1400 plants /feddan (1 feddan = 0.42 h). The experimental design was split split plots design with four replicates. The main plot assigned for levels of irrigation water supplies(100% IR , 75% IR and 50% IR), sub plots was assigned for halophytic plant species (*Atriplex halimus* and *Leucaena leucocephala*) and sub-sub plots was assigned to soil amendments (control, charcoal 4 kg / plant and hydrogel 20 g/ plant). Total irrigation water (m^3/fed.) was calculated from the meteorological data of the Central Laboratory for Agricultural Climate (CLAC) depending on Penman-Monteith equation, the seasonal irrigation water applied was calculated and amounted 1500 m^3/fed. For the treatment of(100 % IR), 1125 m^3/fed (75 % IR) and 750 m^3/fed (50 % IR). Irrigation system was drip irrigation, with water EC 6.85 dSm^{-1}, analyses of water irrigation are presented in Table (2). Irrigation was carried out using sprinkler irrigation system where water was added every 3 days by applying the specified IR (100, 75 and 50 %). Physical and chemical analyses of the soil site were also carried out by using the standard method described by [10], results are presented in Table (3). 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

Table 1: Classification of the two halophytes plant species

Name	*Atriplex halimus*	*Leucaena leucocephala*
Division	Angiosperms	Magnoliophyta
Class	Eudicots	Eudicots
Order	Caryophyllales	*Fabales*
Family	Amaranthaceae	*Fabaceae*
Sub-Family	Chenopodioideae	*Mimosaceae*
Genus	Atriplex	*Leucaena*
Species	halimus	*leucocephala*

Table 2: Chemical analyses of irrigation water

pH		6.85
EC dS^{-1}		4.32
Soluble cations Meq/L	K^+	0.52
	Na^+	55.22
	Mg^{++}	14.65
	Ca^{++}	18.76
Soluble anions Meq/L	SO4--	26.04
	Cl-	54.62
	HCO3-	2.81

Table 3: Mechanical and chemical analyses of the experimental soil site

	Depth	
Soil characteristic	0-30	30-60
EC (m mohs/cm)	8.1	6.6
HCO3%	3.6	3.4
SO4%	42.6	31.8
Cl%	112.7	55.8
Ca (ppm)	54.2	32.6
Mg (ppm)	35.2	31.8
K (ppm)	0.28	0.25
Na (ppm)	87.3	55.9
pH	7.8	7.8
Organic C	9.68	8.69
Soil Texture	Sandy soil	

(46.5% N) Fertilizers were applied on three equal doses at transplantation and after 50 and 100 days from transplantation. Vegetative sample was taken after 210 days from transplanting. Four replicates were taken for each treatment to determine plant height and biomass production (fresh weight g /plant). Chlorophyll a+b in the leaves (mg/g fresh weight) according to [11], proline (µg/g) according to [12]. 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 [13]. The dried plants were then thoroughly ground to fine powder andtotal nitrogen percentage was determined according to the method described by [14]. 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 [15]. The contents of sodium and potassium were determined in the digested material using Jenway flame photometer as described by [16]. K/Na ratio was also calculated for each treatment.The obtained data were subjected to statistical analysis of variance described by [17].

RESULTS

Effect of Water Stress Conditions and Some Soil Amendment on Plant Height, Fresh Biomass, Crude Protein % and Chl.a + Chl.b of *Atriplex and Leucena*: Data presented in Table (4) reveal significant differences due to the third order interaction (IR treatment x plant species x soil amendments) on plant height, fresh biomass, crude protein% and chl.a + chl.b content. The highest values for plant height (118.1 cm) was recorded in *Leucaena*plants under 100% IR treated with hydrogel. Whereas, Atriplex plants produced the highest values of fresh biomass (829.5 g/ plant) under 100 % IR and hydrogel treatment. Gradual decrease of IR caused significant decrease in plant height and biomass weight, while application charcoal and hydrogel significantly enhanced plant height and fresh biomass as compared with control treatment. Over the effect of all treatments, *Atriplex* plants surpassed *Leucaena*and produced more fresh biomass (861.8 g/plant) compared to*Leucaena* (609.4 g/plant).

As for crude protein %, the highest values (9.72%) was recorded in *Atriplex* plants under 50% IR treated with Charcoal as soil amendments. Results in the same table revealed that, Water stress showed significant increased in crude protein %. Data in the same Table (4) showed that, although, statistical analysis recorded nonsignificant differences between soil amendments and control on crude protein %, data presented showed that application of charcoal recorded the highest value of crude protein %. However, *Atriplex* have higher values of CP than *Leucaena*, whereas, the highest values of Chlorophyll a+b (5.89 mg/g fresh wt.) was recorded in *Leucaena* plants grown under 100 % IR and treated with charcoal. Regardless the other two studied factors, water stress treatments significantly decreased Chlorophyll a+b content. Moreover, charcoal and hydrogel significantly enhanced crude Chlorophyll a+b content with superiority to charcoal treatment. However, *Leucaena* have higher values of Chlorophyll a+b than *Atriplex*. Similar results were obtained by [18].

Data presented in Table (5) reveal significant differences due to the third order interaction (IR x plant species x soil amendments) on the content of proline (µg/g dry weight), soluble carbohydrates %, potassium and sodium (mg/g dry weight) as well as succulence and K/Na ratio. The highest values of proline, soluble carbohydrates and sodium amounting to (449.88 µg/g dry wt., 45.87% and 21.89 mg/g dry weight) were recorded in *Atriplex* plants grown under 50% IR without application soil amendments. Whereas, *Atriplex* plants produced the highest values of succulence (3.87) and potassium content (15.45 mg/g dry weight) were obtained in100 % IR and hydrogel treatment, in the same concern, *Leucaena* plants recorded the highest values of K/Na ratio with 50 % IR and control treatment.

However, decreasing of irrigation water supplies as the present from full water requirements showed caused significant decrease in succulence and potassium contents except at 50 %, whereas, an increase in the content of proline, soluble carbohydrates , sodium and K/Na ratio. Moreover, addition of either charcoal or hydrogel significantly enhanced succulence except potassium as compared with control treatment. Concerning the effect of plant species treatment, *Atriplex halinus* produced higher values for all studied physiological aspects than *Leucaena leucocephala*. However, the differences between plant species was nonsignificant. Similar results were obtained by [18].

Table 4: Effect of water stress and some soil amendment on plant height, fresh biomass, Crude protein % and Chl.a + Chl.b of *Atriplex and Leucena*

Irrigation Requirement	Plant species	Agriculture treatments	Plant height cm	Fresh biomass g/plant	Crude protein %	Chl.a + Chl.b mg/g fresh wt.
100% IR	*Atreplixhalimus*	Control	96.2	888.3	8.69	4.23
		Hydrogel	99.6	1035.7	9.02	4.31
		Charcoal	97.1	911.4	9.35	4.87
	Leucaenaleucocephala	Control	110.2	697.5	7.65	5.32
		Hydrogel	118.1	829.5	7.99	5.36
		Charcoal	115.4	763.7	8.02	5.89
75% IR	*Atreplix halimus*	Control	86.5	817.5	9.02	4.12
		Hydrogel	98.9	992.9	9.15	4.15
		Charcoal	94.1	956.2	9.41	4.65
	Leucaena leucocephala	Control	93.3	571.9	7.85	5.02
		Hydrogel	105.3	688.1	8.22	5.12
		Charcoal	99.8	649.9	8.41	5.55
50% IR	*Atreplix halimus*	Control	70.3	656.1	9.15	4.02
		Hydrogel	78.1	780.2	9.52	4.12
		Charcoal	73.5	718.3	9.72	4.36
	Leucaena leucocephala	Control	61.4	400.0	7.52	4.09
		Hydrogel	65.2	456.3	8.01	4.32
		Charcoal	67.6	427.6	8.32	4.44
IR mean		100% IR	106.1	854.4	8.45	5.00
		75% IR	96.3	779.4	8.68	4.77
		50% IR	69.3	573.1	8.71	4.23
Plant species mean		*A. halimus*	88.3	861.8	9.23	4.31
		L. leucocephala	92.9	609.4	8.00	5.01
Soil amendment mean		Control	86.3	671.9	8.31	4.47
		Hydrogel	94.2	797.1	8.65	4.56
		Charcoal	91.2	737.9	8.87	4.96
LSD 5%		IR	5.32	35.6	NS	0.21
		Plant species	NS	37.6	0.51	0.2
		Treatment	4.36	34.2	NS	0.23
		IR x C x T	8.36	62.3	0.88	0.39

Effect of water stress and some soil amendment on some physiological aspects of *Atriplex and Leucena*

Table 5: Effect of water stress and soil amendment on some physiological aspects of halophytic species

Irrigation Requirement	Plant species	Agriculture treatments	Proline content µg/g dry wt.	Soluble carbohydrates %	Succulence	Sodium content mg/g dry weight	Potassium content mg/g dry weight	K / Na ratio
100% IR	*Atreptix hatimus*	Control	395.36	41.36	3.65	19.85	14.65	1.36
		Hydrogel	356.21	40.87	3.87	18.05	15.45	1.17
		Charcoal	374.25	41.12	3.77	18.88	15.17	1.24
	Leucaena leucocephala	Control	321.36	40.58	3.02	16.45	12.00	1.37
		Hydrogel	280.25	39.36	3.25	14.53	13.10	1.11
		Charcoal	295.36	40.12	3.14	15.25	12.80	1.19
75% IR	*Atreptix hatimus*	Control	415.23	43.66	3.35	20.86	13.50	1.55
		Hydrogel	370.23	42.65	3.52	18.77	14.02	1.34
		Charcoal	387.36	43.87	3.50	19.60	13.95	1.41
	Leucaena leucocephala	Control	326.58	42.36	2.88	16.77	11.59	1.45
		Hydrogel	289.58	42.12	3.11	15.08	12.40	1.22
		Charcoal	300.23	42.33	2.96	15.57	11.95	1.30
50% IR	*Atreptix hatimus*	Control	449.88	45.87	3.28	21.89	13.12	1.67
		Hydrogel	403.17	44.23	3.47	20.34	13.70	1.48
		Charcoal	422.69	45.65	3.42	21.29	13.65	1.56
	Leucaena leucocephala	Control	359.61	43.26	2.65	18.31	10.75	1.70
		Hydrogel	316.26	43.02	2.85	16.33	11.60	1.41
		Charcoal	330.55	43.12	2.74	16.99	11.03	1.54
IR mean		100% IR	337.13	40.57	3.45	17.17	13.86	1.24
		75% IR	348.20	42.83	3.22	17.77	12.90	1.38
		50% IR	380.36	44.19	3.07	19.19	12.31	1.56
Plant species mean		*A. hatimus*	397.15	43.25	3.54	19.95	14.13	1.42
		L. leucocephala	313.31	41.81	2.96	16.14	11.91	1.37
Treatment mean		Control	378.00	42.85	3.14	19.02	12.60	1.51
		Hydrogel	335.95	42.04	3.35	17.18	13.38	1.29
		Charcoal	351.74	42.70	3.26	17.93	13.09	1.37
LSD 5%		IR	18.47	2.25	0.17	0.94	NS	0.07
		Plant species	19.68	NS	0.16	1.01	0.66	0.08
		Treatment	18.88	NS	NS	0.97	NS	0.08
		IR xPS x T	34.25	4.02	0.31	1.88	1.23	0.15

DISCUSSION

Halophytes are distinguished from glycophytes by their increased tolerance of abiotic stress conditions. The use of halophytic plants for pasture and fodder production in saline soils is often the only economically feasible solution available [19]. *Atriplex* and *Leucaena* dominate in many arid and semi-arid regions of the World, particularly in habitats that combine a relatively high level of soil salinity with aridity [20]. *Atriplex* plant is highly saline adapted, where the salts are excreted by the formation of small vesicles filled with salt on the surface of the leaves and the vesicles explode leaving the salts out of the plant. Moreover, Leucena is one of the most efficient legume plants in stabilizing atmospheric nitrogen with more than 300 kg N / ha., Leucena leaves are used for organic fertilization [3].

Drought resistance is a complex trait involving several interacting mechanisms and there is increasing interest in studying the physiological behavior of xerohalophytic species in order to identify and understand their drought-resistance mechanisms. These plant species are well adapted to harsh environmental conditions and may therefore provide useful material for Plant breeding programs and identification of the physiological mechanisms and genes involved in a biotic stress resistance [21]. In this concern, [22] investigate the simultaneous occurrence of salt and water stresses in *Atriplex canescens*, they concluded that the effects of both stresses are not strictly additive in reducing plant performance and that tolerances to water and salt stress are linked through a common mechanism of Na uptake for osmotic adjustment. A plant in drying soils is exposed to increasing levels of both water deficit and osmotic stress because the soil matrix potential decreases simultaneously with decreasing soil moisture. Even if osmotic adjustment occurs, a decrease in the hydraulic conductivity of root membrane is observed and it has been clearly demonstrated that the impact of Na^{+1} on water-channel function is not due to its osmotic effect.

Many researchers showed that, charcoal could be used to improve soil fertility and sequester carbon for reduction of carbon mitigation to mitigate climate change [9]. Charcoal has also been shown to change soil biological conditions in terms of the quality and quantity of soil microorganisms [23]. According to [24], these changes may well have effects on nutrient cycles and soil structure which in turn can lead to differences in plants growth and productivity.

Recently, possibilities of application of hydrogel in agricultural field have become increasingly important and have been investigated to alleviate certain agricultural problems like water stress and soil water losses. The literature on the use of hydrogel in agricultural crops and its effects on growth, yield attributes, nutrient uptake and consumptive use of water are considered very important especially in arid zones. [25] reported that super absorbent polymers influenced hydrophilic property, irrigation efficiency, effects under drought stress and optimize water use efficiency of cash crops in arid and semi-arid regions. [26] conducted an experiment with three amounts of superabsorbent polymer 0, 2, 4 g and four levels of irrigation regimes (irrigation at 20, 40, 60 and 80% field capacity, they reported that highest root length (19 cm) with 80% of field capacity irrigation. They added that super absorbent polymers influenced optimum use of fertilizers in cash crops in arid and semi-arid regions. It was also reported that irrigation withholding conditions with hydrogel at different growth stages increased protein percentage [27]. The presented study, results indicated that the growth of *Atriplex halimus* was less affected by conditions of high water stress. This may be attributed to different physiological characteristics of plants exposed to water stress. Similar results were reported by [28], they investigated the effect of water stress on the growth of two *Atriplex* species (i.e., *A. halimus and A. nummularia*). They reported that water stress decreased the dry weight of both plant species. Moreover, [29] on an experiment on *Atriplex* species stated that, both K and Na are involved in the osmotic adjustment of leaf tissue to low external water potential. Sodium may assume a specific physiological function in this xerohalophytic C_4 species. Thus, gaining information on plants originating from different habitats and thus likely to exhibit different adaptive strategies to cope with water stress could help in the selection of suitable genotypes of this species for semi-arid regions of the world.

CONCLUSION

Adopting halophytic plant species which has an economic utilization may enable the rehabilitation and revegetation of salt-affected lands especially under water stress and water salinity, also accepting appropriate soil amendment and irrigation management are the vital concept in managing unfavorable conditions.The present results showed that both*Atriplex halimus* and *Leucaena leucocephala* are highly salt and drought tolerant plant, these plants has the ability to complete its life cycle under very hard conditions. However, addition of either charcoal or hydrogel enhanced biomass production as well as photosynthetic pigments content and crude protein as well as improve the physiological aspects of the plant, with superiority to charcoal treatments. Moreover, hydrogel amendment improved biomass production of both *Atriplex* and *Leucaena* especially in sandy soils.

ACKNOWLEDGMENT

The Authors express their appreciations to the National Research Centre who financed the project of “Some farming Practices for mitigation the expected negative impact of climate changes on field crops and water resources in Egypt” (Project number 11080308).

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