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RESPONSE OF *BALANITES AEGYPTIACA* (L.) DEL. *VAR. AEGYPTIACA* SEEDLINGS FROM THREE DIFFERENT SOURCES TO WATER AND SALINITY STRESSESS

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Abstract

Water and salinity are main co-occurring stresses affecting plant growth and development in arid lands. In this study interactive effects of water and salinity stresses on *Balanites aegyptiaca* seedlings from three different sources (SD5.1, SD6.2 and KSA) were assessed in potted experiment under greenhouse conditions. The effect was measured on stomatal conductance (G_s), specific leaf area (SLA), seedling quality (Shoot to Root ratio (S/R), Dickson Quality Index (DQI) and Sturdiness Quotient (SQ)), Nutrient uptake (N content, K/Na and Ca/Na ratios) and growth. The seedlings were either watered twice a week (well watered) or every two weeks (water stressed), in addition to four salt concentrations (fresh water as control, 5 dS m^{-1}, 7 dS m^{-1} and 9 dS m^{-1} EC). Water and salinity stresses resulted in reduced G_s, SLA, DQ, SQ and S/R, associated with lower height and root collar diameter. However, irrespective of salt concentration, water stressed seedlings displayed substantial reduction in G_s, indicating that G_s is among the most important water conservation strategy for this species. S/R also, remarkably decreased in water stressed seedlings, but, within watering treatment it was increased with increasing salt concentration. SLA and DQI were more affected by salinity stress, due to the increased leaf weight with increasing salinity. N content was more sensitive to water stress than salinity. Both Ca/Na and K/Na ratios were decreased with increasing salt concentration. The three sources exhibited significant variation in their response to water and salinity stresses. SD5.1 displayed higher values in most of studied traits. G_s and S/R may be considered as fitness responses of this species to water stress, while DQI, SLA and K/Na can serve as good indicators to measure response to salt stress.

Key words: Stomatal conductance, Shoot to root ratio, Dickson quality index, Sturdiness quotient, K/Na ratio, Water stress, Salinity stress.

Introduction

Water and salinity represent major co-occurring environmental stresses that regulate plant distribution and development in arid lands. Theses stresses restrict plants establishment and growth (Munns, 2002). In order to survive in such conditions, plants tend to develop different morphological and physiological responses to withstand water and salinity stresses (Kozlowski & Pallardy, 2002). Examples of these responses are stomatal conductance, changes in root/ shoot ratio, growth morphological and physiological attributes and seedlings quality index.

Stomatal conductance is degree of opening of the stomata, which controls diffusion of carbon dioxide (CO_2) from the atmosphere to the plants and loss of water through transpiration. It affects plant growth and development through photosynthesis and control of transpiration. Under water stress conditions plants tend to close their stomata to reduce water loss through transpiration (Diaz-Lopez *et al.,* 2013). G_s is serve as important physiological response of plants to water stress (Warren *et al.,* 2004) that directly decreased with an increase in water stress (Wang, 2012). It is also, one of the physiological processes that response to various degrees of salinity (Abbruzzese *et al.,* 2009) and varies between different genotypes in their response to salinity stress (Kchaou *et al.,* 2013). Specific leaf area (SLA) a very important plant growth analysis trait is directly related to growth rate (Amanullah *et al*., 2013) and species survival (Vile *et al*., 2005).

Many plant growth attributes enable tree seedlings to tolerate environmental stress in the field, hence better field establishment (Grossnickle, 2012). Dickson quality index (DQI) is considered as one of the important measure of seedlings quality (Binotto *et al.,* 2010). It is also, positively correlated to seedlings survival and used as good indicator to predict seedlings performance later in the field (Bayala *et al.,* 2009).

Water stress largely results in less N content. The water stress causes reduction in transpiration rate, which decrease the transport of N from the roots to the shoots (Alam, 1999). The NaCl accumulations in the soil affects both plant cell water potential through the increase of the osmotic potential and interfere with uptake of other nutrient elements. Under saline conditions plants tend to uptake more Na compared to K and Ca (Alam, 1999). K/Na ratio is very important in plant salinity strategies. Higher Na concentration may lead to low K uptake, which will result in low K/Na ratio. K is very important element due to its relation to osmotic regulation as well as stomata opening. Opening and closure of the guard cells is largely regulated by the presence of K (Zhao *et al.,* 2012). Where the importance of Ca is not only on its role in growth, but also, helps in maintaining K uptake (Subbarao *et al.,* 1991).

Among species intra-specific variation in adaptive traits is important to select best seed sources that match planting sites (Zobel & Talbert, 2003). This type of variation is very important for the species to co-adapt to the changing environments. It is well known that *Heglig* tree spreads across a very wide range of environments that are differing in rainfall, altitude and soil types (Elfeel & Warrag, 2011; Hall, 1992). This environmental variation has resulted in considerable genotypic and phenotypic variations among different populations (Abasse *et al.,* 2011; Elfeel *et al.,* 2009).

The value of this tree as arid zone tree species is in its valuable multi-products (Anon., 2008). For example the seed contains a large amount of oil rich in saturated fatty acids and with high stability (Gardette & Baba, 2013). The oil can be consumed by humans (Obidah *et al.,* 2009), in medicinal purposes (Hanan *et al.,* 2010) or to produce biodiesel (Gutti *et al*., 2012; Chapagain *et al*., 2009). The remaining cake can be utilized for animal feed (Morkaz *et al.*, 2011). Other important product is the saponin produced from the fleshy pulp or the kernel, which have molluscicidal activity against schistosomiasis hosting snails (Molla *et al.,* 2013) or can be used to protect crops from mealy bugs (Patil *et al.,* 2010), to control mosquito (Wiesman & Chapagain, 2003) or as antitumor (Gnoula *et al.,* 2008). The tender leaves and fruits are consumed as dry season food (Okia *et al.,* 2011). The whole tree is considered as very important dry season shade and fodder for livestock (Elfeel & Warrag, 2011) or planted for shelterbelts and agroforestry (Gideon & Verinumbe, 2013; Kassa *et al.,* 2010). The wide range of variation exhibited by this species and the multi-products highlights the urgent needs to domesticate this species in dry lands (Wiesman, 2007).

The aim of this study was to investigate intra-specific variation and response of three different sources of *Balanites aegyptiaca* to water and salinity stresses. Water and salinity stresses are among the main stress factors in dry arid environments that affect seedlings survival and first year establishment. Selecting the best source that matches the conditions of arid environments may be quite necessary to ensure better field establishment. Also, understanding the adaptive responses of this species to water and salinity stresses may help in improving best genotypes for arid environments.

Materials and Methods

Seed sources: Seeds of *Balanites aegyptiaca* were obtained from three varied geographical sources. Two sources were brought from Sudan in different ecological zones (zone 5.1 for Blue Nile and 6.2 for Nuba Mountains) as delineated in Sudan tree seed zone (Aelbaek & Kananji, 1995), while the third source was collected from King Abdulaziz University Experimental Farm at Hada Al-Sham area. The three sources were coded as SD5.1, SD6.2 and KSA throughout this study.

Experimental design: The experiment was carried out in a green house located in Hada Al-Sham Experimental Farm, King Abdulaziz University during the year 2013. The seeds from the three sources were immersed in cold water and left to soak for 24 hours. The imbibed seeds were sown in plastic bags (15 x 30 cm when flat) in a mixture of sand, clay and beat moss at a proportion of (1: 1: 1 v/v) in the nursery. After six months of sowing the seedlings were transferred in large round nursery containers in the green house. The seedlings were then left to stand for one month with regular watering as recovery and establishment period, before water and salinity stresses were imposed. The containers were arranged in the greenhouse bench in split-split plot design with three replicates. The whole plot treatment was represented by irrigation, split plot treatment was occupied with salt treatment and the sources were fitted in the split-split plots. In irrigation treatment seedlings were either watered twice a week (normal watering) or every two weeks (water stressed). NaCl salinity treatments used were: fresh tap water as control plus three salt concentrations corresponding to 5 dS m^{-1}, 7 dS m^{-1} and 9 dS m^{-1} EC. The concentrations were made by mixing NaCl salt with fresh water in large plastic tanks and adjusting by portable EC Meter to the appropriate conductivity for each corresponding concentration. At every month the containers were leached with fresh tap water to avoid accumulation of salts in the containers.

Stomatal conductance (G_s) measurement: G_s were measured in two seedlings per source per salt treatment per irrigation. In each of the two seedlings five fully expanded leaves were measured at the abaxial site of the leaf with steady state leaf porometer upgraded model SC-1, 2011 (Decagon, 2011). Four measurements were made at four weeks interval. Before every measurement the instrument was re-calibrated to ensure accurate G_s readings. All the measurements were done during the early morning.

Specific leaf area (SLA): For determination of SLA, five fully expanded leaf samples were collected from two seedlings per source per salinity treatment and per irrigation. The fresh leaves were scanned with colour high resolution scanner. The scanned leaves were processed using digital image tool analysis software package version 3.0 (Anon., 2002) to get leaf area. The leaves were then oven-dried at 65°C for 72 hours and dry weight was recorded. SLA (cm^2 g^{-1}) was calculated as the ratio of leaf area to leaf mass.

Minerals analysis: N, Na, K and Ca were analyzed in leaves samples. N was analyzed with automated micro-kjeldah analyzer, where Na, K and Ca were analyzed with atomic absorption spectrophotometery, then K/Na and Ca/Na ratios were calculated.

Seedlings growth and quality: At the ends of the experiment seedlings height (HT) and root collar diameter (RCD) were measured. After that the seedlings were harvested and partitioned into shoot and root, oven-dried at 65 °C for 72 hours, then shoot dry weight (SDWT), root dry weight (RDWT) and total dry weight (TDT) were obtained. Shoot to root ratio (S/R) was calculated to determine biomass partitioning. Sturdiness Quotient (SQ) was calculated as seedlings height divided by root collar diameter (HT/RCD), while Dickson's Quality Index (DQI) was calculated as total seedling dry weight divide by a sum of sturdiness quotient and shoot to root ratio TDT/(SQ + S/R).

Data analysis: A two way analysis of variance (ANOVA) was done to determine the effects of the mean factors and their interactions, while the means were separated with the Fisher's Least Significant Difference (LSD). The data were analyzed using Statistical Analysis Software version 9.2 (Anon., 2008).

Results and Discussion

Stomatal conductance (G_s): A response of stomatal conductance to water and salinity stresses produced high significant differences (Table 1). Both water and salinity treatments showed very high effects on G_s across the four measurements. G_s, was also, significantly differed among the three sources. Interaction effects of source and watering treatment was not significant throughout the four measurements. Whereas the effects of source and salinity interaction was significant in almost all measurements (Table 1). These findings reflect that source ranking in respect to water stress was consistent, while source ranking between different salt concentrations was not consistent. The change in ranking among the three sources between different salt concentrations can be explained by the data in Table 2. Under control and low salt concentration KSA obtained less G_s values than SD5.1 and SD6.2, while the situation was reversed under higher salt concentrations KSA ranked higher than SD5.1 and SD6.2. KSA was collected from dry zone area of Hada Al-Sham with very high salinity, while both SD5.1 and SD6.2 were obtained from two low rainfall savannah with relatively good soil properties. Values of G_s was remarkably reduced to a very low levels in watered stressed seedlings compared to well watered seedlings irrespective of salinity effect (Table 2). This reduction reflects adaptation of this species to water stress. It is known that G_s is very important water conservation strategy in plants under water stress conditions (Diaz-Lopeza *et al.,* 2013). Thus, G_s may be one of the most important response mechanisms to water stress for this species. Under shortage of water plants close their stomata to reduce water loss by transpiration. Similar results were obtained where stomatal conductance showed a linear decrease in relation to water stress (Khakwani *et al*., 2013; Wang, 2012).

It is well known that *Balanites* in their natural distribution range is considered as a true arid zone species which thrive under very high water stress conditions (Hall, 1992). The significant differences between the different sources in their response to water and salinity stresses may be attributed to genetic differences between sources. Similar results were obtained where *Balanites* from different sources varied in their response to salinity stress (Elfeel *et al.,* 2013) and drought stress (Mahmoud, 2012).

Table 1. ANOVA results for the effects of the main factors and their interactions on Stomatal Conductance (G_s).

Source	D.F.	Observations			
		1	2	3	4
Salt trt	3	**	**	**	**
Irrigation trt	1	**	**	**	**
Source	2	*	**	NS	**
Salt* source	6	**	NS	**	**
Irrig* source	2	NS	NS	NS	NS
Salt* irrig*source	6	NS	NS	NS	NS

* = ≤ 0.05, ** = ≤ 0.01, NS = Not-significant

Table 2. Effect of water and salinity stresses on three different sources of *Balanites aegyptiaca* seedlings stomatal conductance (G_s) (mmol $m^{-2}s^{-1}$) under greenhouse conditions.

Main factors			Observations			
Watering	Salt concern	Sources	1	2	3	4
Well watered	Control	KSA	129.2 ± 29.2	203.2 ± 86.8	125.1 ± 0.7	112.2 ± 2.8
		SD5.1	146.7 ± 18.7	168.5 ± 19.4	184.7 ± 16.5	117.3 ± 0.7
		SD6.2	146.6 ± 8.5	160.7 ± 65.2	126.2 ± 0.7	110.8 ± 2.3
	5 dS m^{-1}	KSA	88.9 ± 31.2	216.2 ± 28.4	152.5 ± 31.1	154.6 ± 11.9
		SD5.1	93.3 ± 20.0	133.4 ± 1.2	127.1 ± 0.9	99.2 ± 8.8
		SD6.2	103.6 ± 19.7	226.5 ± 45.5	129.3 ± 0.5	98.4 ± 5.4
	7 dS m^{-1}	KSA	81.7 ± 35.7	86.1 ± 25.5	140.1 ± 17.8	118.1 ± 41.3
		SD5.1	69.8 ± 15.3	63.6 ± 4.6	62.9 ± 2.8	91.1 ± 6.7
		SD6.2	67.8 ± 26.0	89.5 ± 71.2	93.3 ± 6.5	87.8 ± 13.0
	9 dS m^{-1}	KSA	116.0 ± 2.6	126.7 ± 11.5	107.1 ± 42.1	104.1 ± 12.5
		SD5.1	116.2 ± 52.9	86.8 ± 22.9	128.3 ± 11.3	79.9 ± 45.4
		SD6.2	79.7 ± 23.7	95.4 ± 70.2	124.8 ± 0.2	55.9 ± 5.4
Water stressed	Control	KSA	34.0 ± 3.8	73.1 ± 14.1	85.2 ± 8.9	49.7 ± 7.1
		SD5.1	38.4 ± 5.4	37.8 ± 6.8	93.2 ± 19.3	87.6 ± 8.7
		SD6.2	52.2 ± 24.2	53.6 ± 25.1	52.4 ± 9.1	37.6 ± 3.1
	5 dS m^{-1}	KSA	26.6 ± 9.7	70.4 ± 18.2	65.8 ± 0.7	38.8 ± 10.5
		SD5.1	33.5 ± 9.6	59.4 ± 27.2	50.9 ± 17.6	31.7 ± 2.8
		SD6.2	19.7 ± 2.1	77.1 ± 28.4	87.0 ± 4.6	28.3 ± 1.6
	7 dS m^{-1}	KSA	32.0 ± 4.3	52.3 ± 5.9	93.7 ± 14.3	80.5 ± 16.6
		SD5.1	20.4 ± 4.6	40.1 ± 9.9	85.6 ± 18.0	40.8 ± 4.2
		SD6.2	20.4 ± 5.7	47.9 ± 29.8	91.6 ± 11.1	31.3 ± 11.2
	9 dS m^{-1}	KSA	44.5 ± 4.7	58.5 ± 3.2	45.4 ± 6.6	37.0 ± 1.3
		SD5.1	20.8 ± 1.5	40.3 ± 11.6	55.3 ± 7.2	34.5 ± 5.4
		SD6.2	19.9 ± 1.3	47.7 ± 27.1	47.3 ± 12.6	16.3 ± 1.2

Specific leaf area (SLA): Analysis of variance revealed significant differences between irrigation and salinity treatments on SLA (Table 3). However, in both measurements insignificant differences was observed among sources. The results displayed in the first measurement (Fig. 1a, 1b) and second measurement (Fig. 1c, 1d) revealed that SLA values were low in water stressed seedlings compared to well watered seedlings. However, within the watering treatment there was a sharp decline in SLA values with increasing salt concentration. These results may indicate that SLA can be considered as one of the adaptive responses of *Balanites* to water and salinity stresses. The decrease in SLA in water stressed seedlings and higher salt concentrations may be due to interactive effects of salinity and water stresses on SLA. The observed data revealed smaller leaf area under water stressed seedlings accompanied with higher leaf weight under higher salt concentrations. Thus smaller leaves with heavier weight led to very low values of SLA. Although small SLA values was related to low relative growth rate, but it is considered as important survival adaptive response in plants (Vile *et al.,* 2005). Sources ranking was varied in their SLA response to water and salinity effects. Under control and lower salt concentrations SD5.1 and SD6.2 displayed higher SLA than KSA. Where under higher concentrations of 7 dS m^{-1} and 9 dS m^{-1} values of SLA was higher in KSA.

N content and K/Na, Ca/Na ratios: The results obtained in this study revealed significant differences among watering and salinity treatments as well as among the three sources in available nitrogen content in the leaves (Table 3). The results also, reflected that the effects were much higher among the watering treatment compared to salinity treatment. The low values obtained in water stressed seedlings compared to well watered seedlings may be attributed to the low transpiration rate which affects the transport of nitrogen from the roots to the leaves as was indicated earlier by Alam (1999). Also, the very high effects of watering in stomatal conductance obtained in this study support this finding. The low rate of stomatal conductance associated with water stressed seedlings indicate low transpiration rate.

Analysis of variance also, showed significant effects of watering, salinity and source factors on both K/Na and Ca/Na ratios (Table 3). K/Na was remarkably affected by accumulation of NaCl salt (Table 4). This may be related to the effects of Na accumulation on K uptake (Jameetong & Brix, 2009). K is very important element in plant growth and stomata regulation (Zhao *et al.,* 2012). This can be associated to the very low values of stomatal conductance under low salt concentration in water stressed seedlings. Thus the reduction in K/Na obtained in this study was reflected in low seedlings growth. Also, the accumulation of Na salt may be associated with plant water relations. The low Ca/Na ratio under high salt concentration obtained in this study may led low K uptake, as Ca is important element in K uptake (Subbarao *et al.,* 1990).

Seedlings growth and quality: Seedling height and root collar diameter showed significant differences among the main factors (Table 5). Seedlings height was significantly less in water stressed seedlings compared to well watered seedlings. Also, the values of seedling height decreased with increasing salt concentration (Table 6). However, root collar diameter showed no consistent trend among treatments or sources. Reduction in seedlings height came in response to the lower G_s and SLA values, with substantial effects of water stress compared to salinity. Shoot to root ratio showed a significant differences between watering and salt treatments as well as among the different sources (Table 5). Also, results in Table 6, revealed that S/R ratio was remarkably decreased in water stressed seedlings compared to well watered seedlings. However, within watering treatment, S/R increased with increasing salt concentration. The sharp decrease in S/R under water stress conditions may reflect that more carbon was allocated to the roots under water stress conditions. This finding is similar to Mahmoud (2012) who concluded that shoot to root ratio is serve as most important mechanisms for drought tolerance for this species. The increase in S/R under higher salt concentrations, may be attributed to higher leaves weight under higher salt concentrations. This was in accordance to the results obtained for SLA. However, irrespective of salt or water treatments seedlings of this species approximately allocated double the carbon to the root compared to the shoot. This confirms the arid conditions characteristics of this species.

Dickson quality index (DQI) was only statistically significant among salinity treatment (Table 5), and was decreased with increased salt concentration (Table 6). The decreased values of DQI with increasing salt concentration may be attributed to the higher values of shoot to root ratio under higher salt concentrations resulting from heavier leaves under higher salt concentrations. Thus DQI can be considered as a good indicator to measure this species response to salt stress.

Sturdiness quotient (SQ) showed no significant differences among the main factors and their interactions (Table 3). However, the main values across all treatments are relatively higher, indicating more plant height compared to diameter.

Table 3. ANOVA results for the effects of the main factors and their interactions on Specific Leaf Area (SLA) (cm^2 g^{-1}), N content and K/Na and Ca/Na ratios.

Source	D.F.	SLA				
		1	2	N	K/Na	Ca/Na
Salt trt	3	**	**	**	**	**
Irrigation trt	1	**	*	**	**	**
Source	2	NS	NS	**	**	**
Salt*source	6	NS	NS	**	**	**
Irrig*source	2	NS	NS	**	**	**
Salt*irrig*source	6	NS	NS	**	**	**

* = ≤ 0.05, ** = ≤ 0.01, NS = Not-significant

Table 4. Effect of water and salinity stresses on three different sources of Balanites aegyptiaca seedlings N content and K/Na and Ca/Na ratios under greenhouse conditions.

Main factors			Observations		
Watering	**Salt concern**	**Sources**	**N**	**K/Na**	**Ca/Na**
Well watered	Control	KSA	2.51 ± 0.101	5.61 ± 0.300	0.43 ± 0.100
		SD5.1	2.54 ± 0.100	9.29 ± 0.301	0.64 ± 0.101
		SD6.2	2.53 ± 0.100	8.53 ± 0.301	0.70 ± 0.101
	5 dS m^{-1}	KSA	1.92 ± 0.102	3.97 ± 0.301	0.32 ± 0.100
		SD5.1	1.92 ± 0.104	5.18 ± 0.301	0.51 ± 0.100
		SD6.2	2.05 ± 0.100	5.33 ± 0.301	0.40 ± 0.100
	7 dS m^{-1}	KSA	2.04 ± 0.105	1.86 ± 0.162	0.22 ± 0.105
		SD5.1	1.85 ± 0.100	2.22 ± 0.301	0.45 ± 0.100
		SD6.2	1.74 ± 0.100	3.98 ± 0.300	0.40 ± 0.100
	9 dS m^{-1}	KSA	1.85 ± 0.100	1.35 ± 0.300	0.19 ± 0.100
		SD5.1	1.85 ± 0.152	2.27 ± 0.301	0.24 ± 0.101
		SD6.2	1.89 ± 0.107	1.49 ± 0.312	0.17 ± 0.100
Water stressed	Control	KSA	2.28 ± 0.104	5.92 ± 0.300	0.51 ± 0.101
		SD5.1	2.34 ± 0.100	8.35 ± 0.300	0.72 ± 0.100
		SD6.2	2.32 ± 0.102	8.30 ± 0.300	0.78 ± 0.102
	5 dS m^{-1}	KSA	1.69 ± 0.104	3.97 ± 0.808	0.60 ± 0.104
		SD5.1	1.64 ± 0.077	2.90 ± 0.319	0.38 ± 0.100
		SD6.2	1.72 ± 0.104	3.00 ± 0.300	0.39 ± 0.100
	7 dS m^{-1}	KSA	1.87 ± 0.100	1.49 ± 0.301	0.23 ± 0.101
		SD5.1	1.62 ± 0.104	2.35 ± 0.300	0.25 ± 0.121
		SD6.2	1.50 ± 0.102	2.29 ± 0.300	0.46 ± 0.100
	9 dS m^{-1}	KSA	1.52 ± 0.152	1.32 ± 0.297	0.14 ± 0.100
		SD5.1	1.67 ± 0.107	1.41 ± 0.307	0.16 ± 0.100
		SD6.2	1.29 ± 0.100	1.41 ± 0.300	0.19 ± 0.100

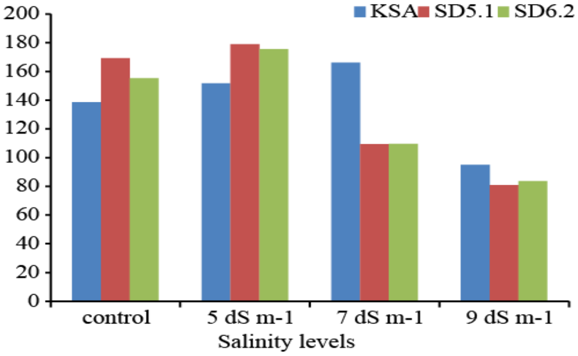

Fig. 1a. Effect of salinity on three different sources of *Balanites aegyptiaca* specific leaf area (SLA) in well Watered seedlings during the first reading.

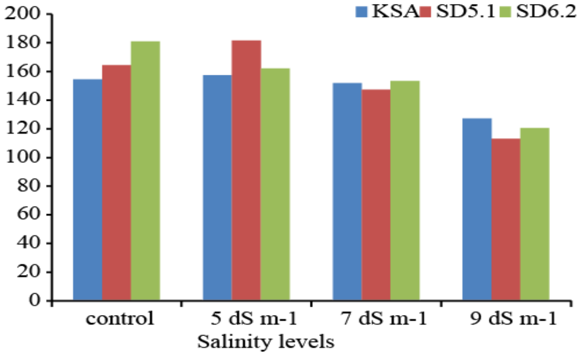

Fig. 1c. Effect of salinity on three different sources of *Balanites aegyptiaca* specific leaf area (SLA) in well Watered seedlings during the second reading.

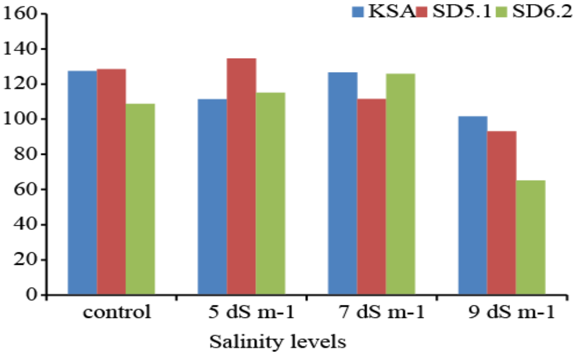

Fig. 1b. Effect of salinity on three different sources of *Balanites aegyptiaca* specific leaf area (SLA) in Water stressed seedlings during the first reading.

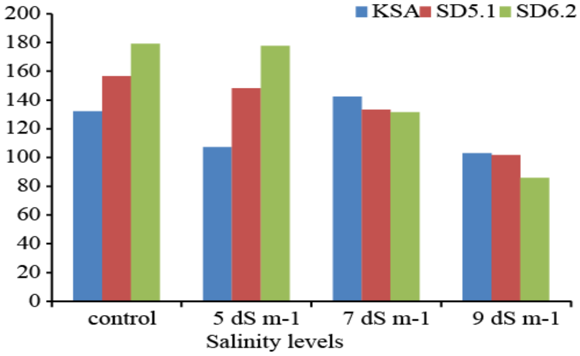

Fig. 1d. Effect of salinity on three different sources of *Balanites aegyptiaca* specific leaf area (SLA) in Water stressed seedlings during the second reading.

Table 5. ANOVA results for the effects of the main factors and their interactions on growth and seedlings quality.

Source	D.F.	Parameters				
		HT (cm)	RCD (mm)	S/S	SQ	DQI
Salt trt	3	**	**	**	NS	**
Irrigation trt	1	**	**	**	NS	NS
Source	2	**	NS	*	NS	NS
Salt*source	6	NS	NS	NS	NS	NS
Irrig*source	2	*	NS	NS	NS	NS
Salt*irrig*source	6	NS	NS	NS	NS	NS

* = ≤ 0.05, ** = ≤ 0.01, NS = Not-significant

Table 6. Effect of water and salinity stresses on three different sources of *Balanites aegyptiaca* growth and seedlings quality under greenhouse conditions.

Main factors			Parameters				
Watering	Salt Concern	Sources	HT (cm)	RCD (mm)	S/R (g/g)	SQ (cm/mm)	DQI
Well watered	Control	KSA	83.0 ± 6.9	6.1 ± 0.2	0.43 ± 0.03	13.6 ± 3.2	1.8 ± 0.96
		SD5.1	89.0 ± 1.4	5.8 ± 0.2	0.43 ± 0.02	15.2 ± 0.2	1.5 ± 0.01
		SD6.2	85.5 ± 2.1	5.6 ± 1.03	0.49 ± 0.01	15.3 ± 2.2	1.3 ± 0.17
	5 dS m^{-1}	KSA	65.5 ± 2.1	5.5 ± 0.5	0.44 ± 0.02	11.7 ± 0.7	1.7 ± 0.51
		SD5.1	85.5 ± 3.4	5.3 ± 0.2	0.45 ± 0.07	15.9 ± 0.8	1.5 ± 0.31
		SD6.2	81.5 ± 0.7	5.5 ± 1.0	0.50 ± 0.07	14.9 ± 0.3	1.7 ± 0.14
	7 dS m^{-1}	KSA	50.0 ± 7.0	4.8 ± 0.08	0.55 ± 0.11	10.7 ± 3.9	1.5 ± 0.48
		SD5.1	72.5 ± 2.1	5.2 ± 0.4	0.57 ± 0.08	13.7 ± 0.6	1.2 ± 0.53
		SD6.2	82.5 ± 4.9	7.8 ± 0.1	0.57 ± 0.08	10.4 ± 0.02	1.6 ± 0.11
	9 dS m^{-1}	KSA	57.0 ± 1.4	3.9 ± 0.2	0.65 ± 0.24	14.5 ± 1.3	0.9 ± 0.35
		SD5.1	76.5 ± 4.9	4.5 ± 0.3	0.54 ± 0.20	16.7 ± 0.1	0.8 ± 0.07
		SD6.2	64.0 ± 2.8	4.0 ± 0.6	0.72 ± 0.24	15.9 ± 3.1	0.6 ± 0.12
Water stressed	Control	KSA	67.0 ± 01.7	5.5 ± 1.7	0.37 ± 0.03	12.5 ± 3.1	1.5 ± 0.05
		SD5.1	55.0 ± 0.7	5.1 ± 0.7	0.35 ± 0.09	10.8 ± 0.02	1.6 ± 0.21
		SD6.2	71.5 ± 0.3	6.1 ± 0.3	0.45 ± 0.01	11.7 ± 2.0	1.6 ± 0.26
	5 dS m^{-1}	KSA	65.0 ± 2.7	6.4 ± 1.4	0.44 ± 0.07	10.4 ± 3.6	1.3 ± 0.37
		SD5.1	72.5 ± 2.0	4.5 ± 1.7	0.43 ± 0.03	15.5 ± 2.7	1.1 ± 0.3
		SD6.2	75.0 ± 2.8	6.7 ± 1.1	0.43 ± 0.11	11.6 ± 3.3	1.8 ± 0.98
	7 dS m^{-1}	KSA	73.5 ± 6.2	5.5 ± 0.1	0.43 ± 0.07	14.6 ± 3.1	1.0 ± 0.30
		SD5.1	74.0 ± 45.6	5.1 ± 2.2	0.47 ± 0.04	14.2 ± 3.6	1.1 ± 0.04
		SD6.2	72.0 ± 4.2	7.2 ± 0.2	0.54 ± 0.07	10.9 ± 04.3	1.1 ± 0.50
	9 dS m^{-1}	KSA	56.5 ± 0.7	5.8 ± 0.9	0.52 ± 0.07	9.7 ± 1.7	1.0 ± 0.35
		SD5.1	64.5 ± 10.6	5.1 ± 3.4	0.48 ± 0.04	15.7 ± 3.8	1.2 ± 1.06
		SD6.2	63.0 ± 7.0	4.4 ± 1.3	0.52 ± 0.02	15.2 ± 6.2	0.9 ± 0.02

Conclusion

The present study showed significant variability of *Balanites aegyptiaca* seedlings in their response to interactive effects of water and salinity stresses. Stomatal conductance was affected by both water and salinity stresses. However, water stressed seedlings obtained very low G_s values compared to well water seedlings. Similar to G_s, S/R ratio and N content were more affected by water stress compared to salt stress. The increase of leaf weight under higher salt concentrations resulted in higher effects on specific leaf area and Dickson quality index. NaCl accumulation in the soil resulted in harmful effect on K uptake leading to low K/Na ratio. There was apparent relationship between the reduction in SLA, DQI and K/Na ratio with G_s and corresponding decrease in seedlings growth.

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