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RESEARCH ARTICLE

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Morpho-physiological response of *Acacia auriculiformis* as influenced by seawater induced salinity stress

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Abstract

Aim of the study: To evaluate the morpho-physiological changes of *Acacia auriculiformis* in response to seawater induced salinity stress along with its tolerance limit.

Area of study: Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh.

Material and methods: Three saline treatments (4, 8, 12 dS m^{-1}) were applied to six-month aged *Acacia auriculiformis* seedlings from January 2014 to June 2014 and the tap water was used as control treatment. To observe salinity effects, the following parameters were measured by using various established techniques: plant height and leaf number, plant biomass, shoot and root distribution as well as shoot and root density, water uptake capacity (WUC), water saturation deficit (WSD) and water retention capacity (WRC), exudation rate, and cell membrane stability.

Main results: Diluted seawater caused a notable reduction in shoot and root distribution in addition to shoot and root density, though plant height, leaf number and plant biomass were found to be decreased to some extent compared to control plants. Water status of the plant also altered when plants were subjected to salinity stress. Nevertheless, membrane stability revealed good findings towards salinity tolerance.

Research highlights: Considering the above facts, despite salinity exerts some negative effects on overall plant performance, interestingly the percent reduction value doesn't exceed 50% as compared to control plants, and the plants were successful to tolerate salinity stress till the end of the experiment (150 days) through adopting some tolerance mechanisms.

Keywords: Salt stress; halophytes; growth parameters; WUC; exudation rate; membrane stability.

Abbreviations used: BSMRAU (Bangabandhu Sheikh Mujibur Rahman Agricultural University); RCBD (randomized complete block design); DATI (days after treatment imposition); RWC (relative water content); WUC (water uptake capacity); WSD (water saturation deficit); WRC (water retention capacity); FW (fresh weight); DW (dry weight); TW (turgid weight); ROS (reactive oxygen species).

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Introduction

Soil and groundwater salinization is one of the oldest and most austere environmental problems, posing critical challenges for the managing of agrarian and natural areas. These problems are pervasive all through the world, affecting circa ~831-950 million hectares, which incorporates 397 and 434 million hectares of saline and sodic soils correspondingly (Teakle & Tyerman, 2010). The most alarming point is that, each year around 1.5 million ha of land are being taken out of production because of excessive salinity levels (Munns & Tester, 2008); and if it proceeds in such way, there are chances that half of cultivable terrains will be lost by the middle of the 21st century (Mahajan & Tuteja, 2005). Due to its annihilate nature, in a few parts of the world salinity is alluding as "Silent Killer" of natural production since it slowly kills plants and soil organism or as “White Death” since it conjures up white images of lifeless shining lands covered with dead trees (Tanji, 1990). High salinity causes diverse cooperative events that adversely affect all plant formative stages (Lee *et al.,* 2013); with corresponding pernicious impacts on the plant yield resulting lessening of agricultural outputs by billions of dollars per annum, with remediation activities being troublesome and costly (Nosetto *et al*., 2013). The rate of plant growth relies upon a couple of principle events, for instance, cell division, cell enlargement and cell differentiation, together with genetic, morphological, physiological, biochemical and ecological activities and their intricate interactions, that are severely overwhelmed by salinity stress (Taiz & Zeiger, 2006; Islam *et al.,* 2015).

Salinity stress not only threats world agriculture, but also jeopardizes Bangladesh food security (Islam *et al.,* 2016). The sustainable livelihoods of millions of people of Bangladesh hinge on agriculture, which acts as a mainstay of the economy, are severely plagued by salinity stress (Abdullah & Rahman, 2015; Haque & Haque, 2016; Islam *et al.,* 2016). In spite of the yield of the alleged salt tolerant shallow rooted glycophytes is severely reduced under ultra-saline soils, the halophyte species can be efficaciously grown in salty environment where the level of saltiness may stretch around 200 mM and more. There are various species of halophytes suited to grow in saline decumbent area (Hasan *et al.,* 2016). However, the fast-growing nature of *Acacia auriculiformis* and its good adaptability in degraded soil condition, especially in saline soils, it has been considered a priority species in the short-rotation plantations in Bangladesh, such as social forestry and agroforestry projects in the coastal belts (Islam *et al.,* 2007, Abdullah *et al.,* 2015). It is a fast growing nitrogen fixing multipurpose tree species which prevents exposure of soils to direct radiation from the sun using its perennial foliage as well as crown cover, and reduce the evaporation rate, resulting in less salt accumulation in the top soils (Tham & Liew, 2012; Khan *et al.,* 2014; Sohel *et al.,* 2016). Furthermore, it is extensively used to provide shade, form windbreaks, and the wood has been used widely for charcoal, fuel, pulp, tool handles, oars, paddles, packing cases, and furniture manufacturing (Shukla *et al.,* 2007; Chowdhury *et al.,* 2013). Therefore, if *Acacia auriculiformis* can be brought under plantation in the saline prone area, the existing agrarian land will be more productive through minimizing the detrimental effects of salts as well as to sustain crop productivity, which will help to maintain a wide range of ecological security.

Nevertheless, salinity tolerance limit alongside morpho-physiological response of *Acacia auriculiformis* to salinity stress is not well understood yet. Therefore, the main goal of this study was to appraise the effect of seawater induced salinity stress on the morphological and physiological features of *Acacia auriculiformis* plants.

Material and methods

A pot experiment was carried out in the research field of the Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) (24º 09` N; 90º 26` E), Bangladesh, from January 2014 to June 2014. The size of every single pot was 28 cm (L.) × 30 cm (W.) and filled with a mixture of soil and cowdung at a ratio of 4:1, which was treated with formaldehyde to curtail soil borne disease. Each pot contained 14.50 kg of soil, which was equivalent to 12.04 kg oven dry soil and holds about 17% moisture at field capacity (FC).

The experiment was conducted in a randomized complete block design (RCBD) with five replications and four treatments. The saline treatment variables were 4, 8 and 12 dS m^{-1} and the tap water was used as control treatment (0 dS m^{-1}). Salinity treatments were prepared by the intermixing of sea water and tap water in different proportion to obtain desired electrical conductivity value. Six months aged seedlings of *Acacia auriculiformis* were used for this study. Ten days after transplanting, the plants were irrigated with either tap water or differently diluted seawater (4, 8, 12 dS m^{-1}) till the end of the experiment.

Plant height and leaf number were measured at every one-month interval by using measuring scale and simple counting method correspondingly. At the end of the experiment, i.e. 150 days after treatment imposition (DAT), for determining total dry mass, plants were removed from the soil and washed in running tap water for a short period of time to eliminate loose soil particles and then they were placed on dry polyethylene sheets to allow any free surface moisture to dry out. After that, plants were divided into root and shoot and, fresh weight was taken through an electronic balance. Thereafter, the leaves were immersed in distilled water for 24 hours at room temperature in the dark. These leaves were weighed to record the turgid (saturated) weight after excess water was removed by gently wrapping the leaves with a paper towel. Plant materials were placed in paper bags afterwards and allowed for oven dry at 80ºC for 72 hours. After oven drying, dry weight of the samples was taken followed by a few minutes of cooling in the dry environment. Shoot and root distributions well as shoot and root densities were measured according to the equation described by Arduini *et al.* (1994) as follows:

Shoot or root distribution = Fresh Mass/Length

Shoot or root density = Dry Mass/Length

Water Uptake Capacity (WUC) was measured by using the following formula (Sangakkara *et al.,* 1996):

$$\mathrm{WUC} = \frac{(\mathrm{TW} - \mathrm{FW})}{\mathrm{DW}}$$

Where,

TW = Turgid weight of the leaf

FW = Fresh weight of the leaf

DW = Dry weight of the leaf

The water saturation deficit was measured by the following formula (Sangakkara *et al.,* 1996):

$$\text{Water Saturation Deficit (WSD \%)} = 100 - \text{RWC}$$

Where, RWC = Relative water content

Water retention capacity (WRC) is the ratio of the turgid weight and dry weight of a tissue and was estimated by the following formula (Sangakkara *et al.,* 1996):

$$\mathrm{WRC} = \frac{\mathrm{TW}}{\mathrm{DW}}$$

Where,

TW = Turgid weight of the leaf

DW = Dry weight of the leaf

The xylem exudation rate was measured at 5 cm above from the stem base of control and stressed plants after 150 days of treatment imposition. At first, dry cotton was weighed. A slanting cut on the stem was made with a sharp knife. Then the weighed cotton was placed on the cut surface. The exudation of sap was collected from the stem for 1 hour at a normal temperature. The final weight of the cotton with sap was measured. The exudation rate (mg h^{-1}) was calculated by deducting dry cotton weight from the sap containing cotton weight and expressed as per hour basis as follows (Akhtar *et al.,* 2013):

$$\text{Exudation rate} = \frac{(\text{Weight of cotton} + \text{sap}) - (\text{Weight of cotton})}{\text{Time (hr)}}$$

Degree of succulence and the degree of sclerophylly was estimated by using the equation as follows:

Degree of succulence = Water amount / Leaf area (Delf, 1912)

Where, water amount = fresh Mass – dry mass

Degree of sclerophylly = Dry mass / Leaf area (Witkoswski & Lamont, 1991)

Membrane stability was assessed by measuring the electrolyte leakage (EL %) from leaf tissue into refined water after 90 and 150 days after treatment imposition using the formula described by Sairam (1994). However, percent reduction value and relative value were calculated using the following equation (Hasegawa *et al.,* 2000).

$$\text{Percent reduction} = \frac{\text{Control treatment value} - \text{Saline treatment value}}{\text{Control treatment value}} \times 100$$

$$\text{Relative value} = \frac{\text{Saline treatment value}}{\text{Control treatment value}} \times 100$$

The data were subjected to one-way analysis of variance (ANOVA) and different letters indicate the significant differences between treatments at $p<0.05$, according to least significant difference test (LSD) analysed using Statistix 10 software package. Data represented in the Tables and Figures are means ± standard errors (SE) of five replications for each treatment.

Results

Salinity stressed plant height and leaf number results indicate that the progressive increase in salinity levels triggers an increase in the percent reduction of the plant height and leaf number over control treatment. This increase reaches the severe level after 150 days after treatment (Fig. 1a, b). Plant height was reduced by 5.56, 21.16 and 29.69% at 4, 8, 12 dS m^{-1} salinity levels, respectively, in relation to the control plants at 150 DAT (Fig 1a). Whereas, the number of leaves reduced by 1.11, 1.20 and 1.30 times compared to that of control plants at the same salinity levels and days after treatment imposition (Fig. 1b).

There was a significant ($P<0.01$) negative effect of salt stress on plant biomass, shoot and root distribution as well as shoot and root density of *Acacia auriculiformis* plants (Table 1). While compared with the values of control plants, it was apparent that the mean values and the percent reduction differences were higher in plants that had been treated with 12 dS m^{-1} salinity level (Table 1), being the total dry mass the variable which suffered the higher reduction (about 50% compared to control plants).

Water uptake is essential for cell expansion and plant growth. The water uptake capacity (WUC) quantifies the ability of a plant to absorb water per unit dry weight in relation to turgid weight; water saturation deficit (WSD) indicates the degree of water deficit in plants, and water retention capacity (WRC) of leaf provides information on the capacity of a plant cell to retain water. With the increase of salinization period and salinity level, mean values of WUC and WSD were increased, while salinization had less effect on the mean value of the water retention capacity of *Acacia auriculiformis* plants (Table 2). In this regard, at 150 days after treatment imposition with 12 dS m^{-1} salinity level,

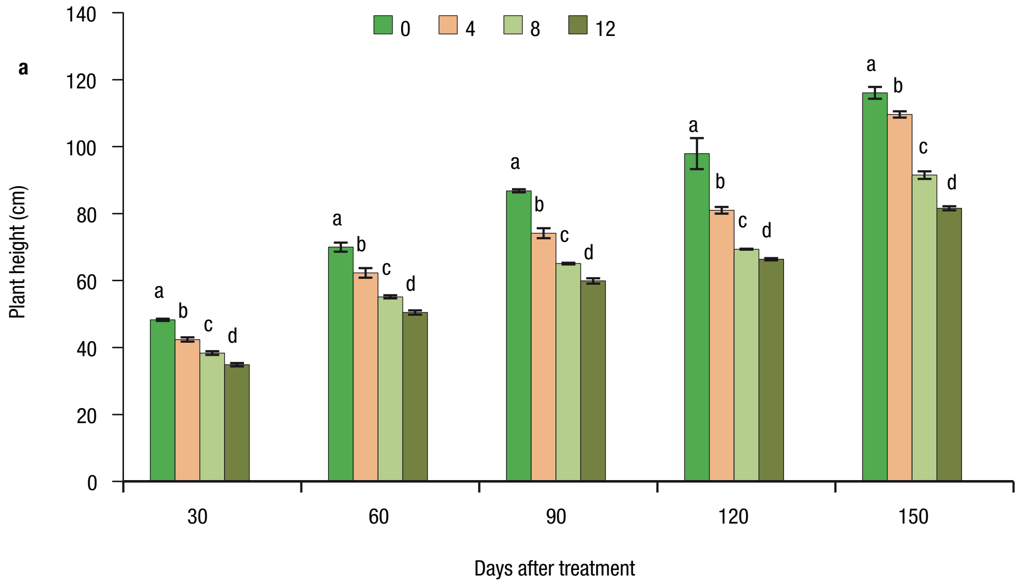

Figure 1. Response of (a) plant height (cm) and (b) number of leaves of *Acacia auriculiformis* to different salinity levels at different days after treatment imposition. Means followed by a common letter are not significantly different at 5% level by LSD. Error bars represent standard error (±). Error bars fit within the plot symbol if not shown.

the plants showed higher relative value (% of control) of WSD (486.16%) and WUC (215.70%) than control plants, while WRC responded in an opposite manner, i.e. it was reduced to 40.88% compared to control plants.

There was no noteworthy difference in the degree of succulence, however, the degree of schlerophylly showed a noticeable divergence between control and stressed plants (Table 3). In response to seawater stress, the mean value of exudation rate showed considerable variations in comparison with those of the control plants (Table 3). The highest percent reduction value (45.51) was noticed under 12 dS m^{-1} salinity level followed by 8 dS m^{-1} as moderate salinity level (35.31).

The membrane stability of *Acacia auriculiformis* plants was significantly increased by the three evaluated levels of salt stress at both measurement periods (Fig. 2). In this regard, after 90 days of treatment imposition at 4, 8 and 12 dS m^{-1} salinity levels, the membrane stability index was significantly ($P<0.01$) decreased by 3.29, 4.36 and 9.62 % respectively, compared with that of control plants. At 150 days after treatment imposition, the membrane stability index was

Table 1. Effect of seawater induced salinity on total fresh mass, total dry mass, shoot and root distribution, shoot and root density of *Acacia auriculiformis* plants after 150 days of treatment imposition

Salinity levels (dS m^{-1})	Total fresh weight (g)	Total dry weight (g)	Shoot Distribution (g cm^{-1})	Shoot Density (g cm^{-1})	Root Distribution (g cm^{-1})	Root Density (g cm^{-1})
Control (Mean Value)	556.93 ± 11.73 a	260.78 ± 4.40 a	3.91 ± 0.07 a	1.96 ± 0.02 a	0.92 ± 0.01 a	0.29 ± 0.003 s
4	446.95 ± 2.30 b (19.74 ± 0.41) c	202.11 ± 2.96 a (22.49± 0.78) c	3.36 ± 0.04 b (14.02 ± 1.07) a	1.63 ± 0.01 b (16.33 ± 0.97) c	0.91 ± 0.006 a (0.58 ± 0.17) b	0.26 ± 0.003 b (10.07 ± 1.26) b
8	365.51 ± 6.45 c (34.37 ± 1.15) b	159.11± 2.70 c (38.71 ± 1.06) b	3.26 ± 0.08 b (16.48 ± 2.27) a	1.56 ± 0.03 b (20.33 ± 2.02) b	0.89 ± 0.01 a (2.18 ± 0.28) b	0.22 ± 0.003bc (20.96 ± 1.30) a
12	314.27 ± 3.38 d (43.57 ± 0.60) a	131.13 ± 1.02d (49.71 ± 0.43) a	3.19 ± 0.02 c (18.20 ± 0.61) a	1.44 ± 0.01 c (26.35 ± 0.89) a	0.84± 0.01 b (7.71 ± 1.68) a	0.21 ± 0.006 c (26.56 ± 2.18) a

Values are means ± SE of five independent replications (n = 5). Different letters within the column indicate statistically significant differences between treatments, according to least significant difference test ($p < 0.05$). Values within parenthesis indicate the percent reduction value over control.

Table 2. Effect of seawater induced salinity on water uptake capacity, water saturation deficit and water retention capacity of *Acacia auriculiformis* plants at different days after treatment imposition

Days after treatment imposition (DATI)	Salinity levels (dS m^{-1})	Water uptake capacity	Water saturation deficit (%)	Water retention capacity
30	Control	0.29 ± 0.04 a	8.97 ± 0.62 c	4.30 ± 0.33 a
	4	0.40 ± 0.03 ab	15.07 ± 1.37 b	3.71 ± 0.13 a
	8	0.40 ± 0.06 ab	20.31 ± 3.02 ab	2.99 ± 0.10 b
	12	0.45 ± 0.02 a	24.38 ± 1.08 a	2.84 ± 0.05 b
60	Control	0.32 ± 0.03 b	9.94 ± 0.73 c	4.30 ± 0.36 a
	4	0.43 ± 0.04 ab	16.22 ± 2.09 bc	3.71± 0.16 a
	8	0.45 ± 0.05 ab	23.10 ± 2.42 ab	2.98 ± 0.14 b
	12	0.53 ± 0.06 a	28.78 ± 3.34 a	2.84 ± 0.03 b
90	Control	0.32 ± 0.05 b	10.57 ± 1.72 c	4.13 ± 0.21 a
	4	0.53 ± 0.07 ab	21.45 ± 3.34 b	3.58 ± 0.20 a
	8	0.54 ± 0.11 ab	27.71 ± 3.40 ab	2.90 ± 0.20 b
	12	0.62 ± 0.11 a	36.72 ± 3.78 a	2.65 ± 0.20 a
120	Control	0.32 ± 0.05 b	10.93 ± 1.47 c	3.90 ± 0.10 a
	4	0.61 ± 0.04 a	27.87 ± 2.66 b	3.24 ± 0.15 b
	8	0.66 ± 0.06 a	37.55 ± 1.72 a	2.76 ± 0.12 bc
	12	0.68 ± 0.08 a	43.64 ± 3.34 a	2.63 ± 0.26 c
150	Control	0.32 ± 0.32 b	11.17 ± 1.83 c	3.93 ± 0.16 a
	4	0.65 ± 0.61 a	33.91 ± 4.19 b	2.96 ± 0.22 b
	8	0.69 ± 0.66 a	47.99 ± 5.80 a	2.49 ± 0.16 bc
	12	0.70 ± 0.69 a	54.31 ± 5.38 a	2.33 ± 0.14 c

Values are means ± SE of five independent replications (n = 5). Different letters within the column indicate statistically significant differences between treatments, according to least significant difference test ($p < 0.05$).

lessened by 2.84, 7.72 and 13.09% at 4, 8, 12 dS m^{-1} salinity levels, respectively (Fig. 2).

Discussion

Plant height represents the growing nature of the plants, which plays an important role in assessing the growth performance of the plant. Irrigation with seawater significantly reduced the plant height of acacia in this study (Fig. 1a). However, the plants continued to grow successfully throughout the duration of the study in spite of higher salinity levels. Reduction in plant height due to salt stress may be attributed to the effects of salts in retarding the processes of cell division and cell expansion upon which growth depends on (Netondo *et al.*, 2004; Radi *et al.,* 2013). The results what we found are conforming to the results of Sohail

Table 3. Effect of seawater induced salinity on degree of succulence, degree of schlerophylly and exudation rate of *Acacia auriculiformis* plants after 150 days of treatment imposition

Salinity levels ($dS\ m^{-1}$)	Degree of succulence ($mg\ cm^{-2}$)	Degree of schlerophylly ($mg\ cm^{-2}$)	Exudation rate ($mg\ h^{-1}$)
Control (Mean Value)	1.43 ± 1.37 a	1.25 ± 0.02 a	1754.0 ± 0.06 a
4	1.39 ± 1.18 a	1.15 ± 0.01 b	1342.0 ± 0.06 b
8	1.37 ± 0.54 a	1.06 ± 0.02 c	1134.6 ± 0.07 c
12	1.36 ± 1.25 a	0.97 ± 0.01 d	995.6 ± 0.03 d

Values are means ± SE of five independent replications (n = 5). Different letters within the column indicate statistically significant differences between treatments, according to least significant difference test ($p < 0.05$).

et al. (2010) on *Ziziphus spina-christi* and Gao *et al.* (2014) on potato plantlets. The number of leaves found to be decreased to progressing salinity levels (Fig. 1b). Inhibition of the formation of leaf primodia under salinity stress could be the probable reason for the reduction in leaf number. The decrease in leaf number may further be carried over due to the accumulation of sodium chloride in the cell walls and cytoplasm of the older leaves. At the same time, their vacuole saps cannot accumulate more salt and, thereby increases the concentration of salt inside the cells, which ultimately leads to their quick death (Munns, 2002). Munns & Tester (2008) also stated that the ion-specific phase of plant response to salinity stress starts when salt accumulates to toxic level in the old leaves (which are no longer expanding, so no longer diluting the salt arriving in them as younger growing leaves do), and they die and cause a decrease in the leaf number. These results are similar to the results of da Silva *et al*. (2008) on *Spondias tuberosa* plants and Mahmood *et al.* (2009) on *Acacia ampliceps*.

Decreasing trend of biomass production (Table 1) under salinity stress might be due to inadequate availability of nutrients present in the growth medium and the decreased water entry rate of the plants and/or the deceased in photosynthetic output with a suppressed supply of CO_2. Corroborate findings was also reported by Qureshi *et al*. (2000) on *Eucalyptus camaldulensis* plants. Nonetheless, shoot and root density represents dry mass production per unit of shoot and root length respectively. In contrast, shoot and root distribution epitomizes fresh mass accumulated per unit of shoot and root length, respectively. The reduction in both density and distribution of acacia biomass in this study may reflect the effect of salinity on decreasing shoot and root biomass (fresh and dry masses). In this respect, Chopart *et al*. (2008) stated that evaluation of shoot/root density and distribution could be considered as a key factor for water and nutrient uptake by a plant from the soil. These results were in harmony with those obtained by Seckin *et al.,* (2010) on barley cultivars and Ali (2009) on wheat cultivars.

Water stress is one of the first and most obvious effects of salinity and thus the determination of water relations is crucial for understanding salinity tolerance mechanisms of a plant (Netondo *et al.,* 2004). Plant water status is important not only for its growth under favourable environmental conditions, but also for its ability to tolerate water deficit and high salt levels (Blumwald, 2000). Additionally, the importance of the internal water balance in plant water relations is generally accepted because of the close relationship between the balance and turgidity to the rates of physiological processes that control the quality and quantity of growth (Aldesuquy *et al.,* 2009). In this experiment, it was found that seawater induced salinity had a conspicuous effect on plant water status (Table 2). The altering of water status may be ascribed by, in transpiring plants; water is thought to come from the soil through osmosis process, and this water goes into the transpiration stream through apoplastic and symplastic pathways. However, seawater stress is responsible for changing the situation because of restricted transpiration. The reduction of transpiration hinders water uptake from the soils because of injury in the root systems, which ultimately causes the disparity of water status in plants. Lower water uptake is thought to be accountable for lessening exudation rate (Table 3). Exudation rate means coming out of sap from a vigorously growing stem of a plant when it is cut off just above the ground level. The results reported by many researchers (Papadopoulos*,* 1987; Pessarakli & Tucker, 1985, Kabir *et al.,* 2005) correspond to the results we obtained.

Salt stress induced a non-significant decline in the degree of leaf succulence, but noticeable divergence was found in the degree of sclerophylly (Table 3). In accordance with our results, leaf succulence was found to decrease in three varieties of salt-stressed sunflower plants and two wheat cultivars (Welch & Rieseberg, 2002; Aldesuquy *et al.,* 2012). This may be explained on the basis that less absorbed water means less water content of the growing leaves resulting in less relative water content. Decreased relative water content aggravates more water saturation deficit, therefore causing less leaf succulence and more sclerophylly (Aldesuquy *et al.,* 2012). On the contrary, in *Bruguiera parviflora*, leaf succulence increased with increasing salinity (Parida *et al.,* 2004). Increased leaf succulence might have resulted from the increase in water uptake and turgor pressure as a result of cells having a higher solute concentration (Jennings, 1976). It is worthy to

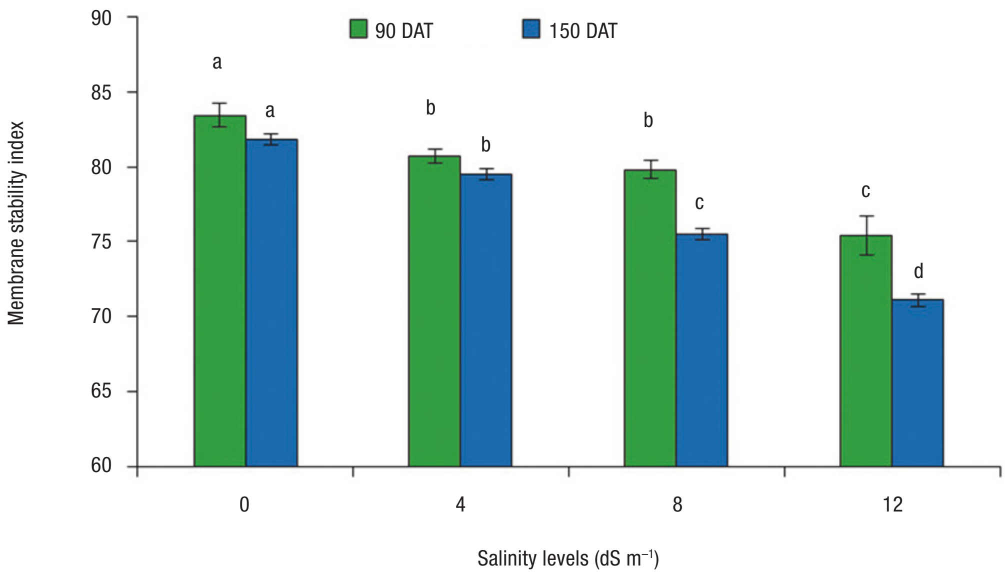

Fig. 2. Response of membrane stability index of leaves of *Acacia auriculiformis* to different salinity levels at different days after treatment imposition. Means followed by a common letter are not significantly different at 5% level by LSD. Error bars represent standard error (±). Error bars fit within the plot symbol if not shown.

mention that the plants having a higher degree of leaf succulence and lower extent of leaf sclerophylly are considered as a salt tolerant plant (Aldesuquy *et al.,* 2012). Degree of schlerophylly is considered as an adaptation feature to water deficit as well as low nutrients in the growth medium. Furthermore, it enhances the leaf longevity by protecting the leaf thereby increasing leaf carbon gain (Edwards *et al.*, 2000) to maintain its physiological process.

The cell membrane, being at the interface between the cells and its surroundings, is the first organelle that is susceptible to salinity stress and the capacity of maintaining its integrity is an important process related to plant resistance against salt stress (Xu *et al.,* 2010; Hichem *et al.,* 2009; Ali *et al.,* 2008). Increasing the salinity level in the present study caused a noticeable decrease in the membrane stability index (MSI) of acacia plants compared with those of the reference control plants (Fig. 2). The integrity of the membrane is disrupted due to peroxidation of lipids by reactive oxygen species (ROS) in the membrane system, resulting in the decrement of membrane stability (Tuna *et al.,* 2013; Kaya *et al.,* 2009; Tuna *et al.,* 2007). This result is in harmony with Abeer *et al.* (2015) found on tomato cultivars and Hassanein *et al.* (2012) on *Vicia faba* L. plants.

It could be concluded that as this study was carried out at the seedling stage, the studied plants showed at some extent a high degree of salt tolerance but performed better at the moderate salinity level. The adverse effect of salinity stress was noticeable to the whole plant and appeared during all developmental stages. The percent reduction in plant morphological characters was conspicuous at the highest level, i.e. 12 dS m^{-1} of seawater induced salinity. Interestingly, at that high salinity level, most of the plant parameters reduced to less than 50% compared to the control plants. Physiological processes of the plants also altered to some extent under elevated salinity levels. Nevertheless, established plants of this species may be tolerant to salt stress higher than the level used in this study because seedlings are more sensitive to high soluble-salt levels than established plants.

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