Variation among *Eucalyptus* Species for Morphological, Physiological and Biochemical Traits under Simulated Salt Stress Conditions

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Abstract

The investigation was conducted on five-month-old seedlings of *Eucalyptus camaldulensis*, *E. pellita*, *E. tereticornis* and *E. citriodora* in earthen pots. Four levels of NaCl concentration i.e., 0, 40, 80 and 120 mM were applied through irrigation to these *Eucalyptus* species arranged in completely randomized design (CRD) in three replications. Significant differences among the species were found for morphological (plant height, collar diameter, root length and total plant length), physiological (relative water content, electrolyte leakage, chlorophyll and carotenoid content) and biochemical (proline, sugar and reducing sugar content) parameters. *E. camaldulensis* registered the highest average values (height 160.07 cm and collar diameter 10.65 mm) for morphological traits whereas the lowest average values (height 100.04 cm and collar diameter 6.82 mm) were in case of *E. citriodora*. Increase in salinity level ultimately led to significant decrease in all the traits indicating a reverse trend between these traits and salinity treatments. Significant reduction in total chlorophyll, carotenoids and relative water content was observed with increase in salinity level. Electrolytes leakage increased as the salinity increased indicating the damage caused by salt stress. Salinity stress raised the content of osmoprotectants such as proline, total soluble sugar and reducing sugar. *E. camaldulensis* was the most tolerant species which performed better than other species even at the highest salinity level and the salinity tolerance of species varied as *E. camaldulensis* > *E. pellita* > *E. tereticornis* > *E. citriodora*. These findings indicate more research into morphological, physiological and biochemical understanding of *Eucalyptus* species for salt tolerance mechanism.

Key words: *Eucalyptus* species, Growth response, Osmoprotectants, Photosynthetic pigments, Salinity tolerance

Introduction

Depending on market demand and site conditions, plantation forestry makes use of a variety of tree species especially *Eucalyptus*, *Populus*, *Pinus*, and *Acacia* (FAO, 2009). Plantation forests continue to meet the growing global demand for timber products (FAO, 2016). Expansion of *Eucalyptus* plantations is expected to continue owing primarily to global demand for pulp in paper industry (Phillips, 2013). The pulp and paper industry are capable of producing products that go beyond paper (Christie, 2008). Furthermore, the unfavorable conflict that occurs when food and biomass production compete for land can be avoided by planting short rotation trees on marginal lands, particularly salt-affected and barren land (Scarlat *et al.*, 2015; Madiwalar *et al.*, 2023).

Factors leading to abiotic stress such as temperature, heat, drought, chemical toxicity, heavy metals and salinity result in oxidative stress which ultimately affects plant development and growth. Like many other abiotic stresses, salinity also inhibits the plant growth and it is expanding rapidly as a result of different irrigation practices around the world (Munns and Gilliham, 2015). However, tolerance level of different plant species may vary (Marschner, 1995; Singh *et al.*, 2020). Around 6.71 percent of inland areas (areas far away from ocean) are affected universally and this issue is rampant in the semi-arid and arid lands of Asia, Africa and Australia. It is approximated that about 20 million hectare of such land is in Southeast Asia alone (FAO, 2015). Soil salinity affects 8.31 billion ha of land, making it an ecological problem worldwide (Munns and Tester, 2008). In India, around 6.75 million ha land is
Eucalyptus is native to Australia and has become an important tree species in India. It has high level of growth rate as compared to other tree species under salt affected conditions, which can be interconnected to its inherent salt-tolerant ability due to some physiological advantages while linking between salt and drought response (Munns, 2002). Saline conditions up to 18 dS m⁻¹ or even more than 31 dS m⁻¹ can be tolerated by Eucalyptus spp. (Akhtar et al., 2008). Presently, even though various salt tolerant cultivars of several agricultural crops are accessible to grow in relatively moderate salt affected soils, still these cultivars sink to harvest the expected yields on high saline soils. With high possibility to grow in saline soils under arid climatic conditions, Eucalyptus species are considered as one of the vital bio-economic tree species (Bennett et al., 2009; Singh et al., 2019). In Eucalyptus spp. biosynthesis of osmoprotectants i.e. soluble sugars, reducing sugars, proline and glycine betaine increased under increasing salt concentrations in order to cope up with salinity stress (Shariat and Assareh, 2016).

The present investigation was conducted to identify Eucalyptus spp. that are tolerant to salinity stress with a holistic approach highlighting differences in plant morphological, physiological and biochemical traits. The study would help in determining salt tolerance ability of four different Eucalyptus species and identify potential mechanisms to enhance their growth and productivity under salt stress.

Materials and Methods

Site description and experimental details

The experiment was conducted at the Research Area of Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana. It is located at 75°78′E longitude and 30°54′N latitude with an elevation of 247 m above the mean sea level. The region’s climate is subtropical to tropical, with scorching summers (May-June) and freezing winters. The region gets majority of its rainfall (700-800 mm) from July to September, with only a few light showers in the winters. The experimental soil had sandy loam texture. The pH, EC, organic carbon, available N, P and K were 7.62, 0.28 dS m⁻¹, 0.32 %, 121.8 kg ha⁻¹, 9.2 kg ha⁻¹ and 178.1 kg ha⁻¹, respectively.

Four different Eucalyptus species were used namely Eucalyptus camaldulensis, E. pellita, E. tereticornis and E. citriodora {Syn Corymbia citriodora}. Seedlings of these different Eucalyptus spp. were planted in earthen pots filled with 4 kg soil and 2 kg FYM (in the ratio of 2:1) in the pots having 30 cm height and 30 cm top diameter. All the plants were irrigated regularly with tap water for first two weeks for initial establishment of seedlings. For better acclimatization of plants, the T1, T2, T3 and T4 pots were irrigated with 0, 20 mM, 40 mM and 60 mM NaCl, respectively for 4 weeks. Later on, the salinity treatments were enhanced to 0, 40 mM, 80 mM and 120 mM NaCl, respectively. The other cultural and management conditions in all the treatments were similar. Irrigation water having these different salt concentrations was applied to the plants of different Eucalyptus spp. under study on every alternate day. The irrigation water volume was determined by adding the leaching amount to the water consumed by the plants i.e., half liter pot⁻¹. Saline water treatments were applied till the harvest of the plants. The pH of the soil increased with an increase in the concentration of NaCl which was 7.70, 8.10, 8.23 and 8.33 at 0, 40, 80 and 120 mM NaCl concentrations, respectively. The EC of soil at 0, 40, 80 and 120 mM NaCl was 0.33, 1.0, 1.54 and 2.53 dS m⁻¹ respectively, at the end of experiment i.e., 7 months after initiation of salinity treatments. The average initial value soil EC was 0.28 dS m⁻¹.

Observations

Growth parameters like plant height (cm) and collar diameter (mm) were measured using a measuring scale and digital Vernier caliper (to the nearest of 0.02 mm), respectively 7 months after planting. At the end of the experiment, plants were harvested and partitioned into four components i.e., leaves, branches, stem and roots. Total plant height and root length were measured using measuring scale. Subsequently, the survival
percentage of the plants was calculated. The physiological parameters viz. relative water content (RWC), electrolyte leakage, total chlorophyll content and carotenoids were determined at the end of the experiment. In the leaves, the RWC was determined by the method developed by Silveira et al. (2003) and the electrolyte leakage (EL) by the method suggested by Fletcher and Drex lure (1980). The method given by Hiscox and Israelstam (1979) was followed for estimation of total chlorophyll content and carotenoid. Osmolyte concentrations, viz. proline, total soluble sugars and reducing sugars content were determined in the treated plants. Proline content in the leaf samples was measured according to the method described by Bates et al. (1973). Total soluble sugars content was determined by the method suggested by Dubois et al. (1956) and the reducing sugars content by the method suggested by Sumners (1935).

Statistical analysis

The experiment was arranged in completely randomized design (CRD) with three replications. Therefore, the data collected were tabulated and analyzed by analysis of variance technique in CRD (Panse and Sukhatme, 1985). The least significant differences (LSD) at 5% level of significance were worked out to separate the means of the treatments.

Results and Discussion

Morphological parameters

Salinity stress had a significant negative impact on plant growth parameters. The seedlings grown under irrigation with high NaCl concentration (120 mM) had the lowest average plant height of 104.75 cm followed by that of those grown at 80 mM (116.82 cm) and at 40 mM (130.32 cm) and finally highest growth (160.07 cm) was attained when the seedlings were irrigated with tap water (control) (Table 1). These results indicate the existence of a reverse relationship between the salinity level and the height of plants. The average plant height differed significantly among Eucalyptus species with different treatments. The mean height (160.07 cm) of E. camaldulensis was significantly greater than other three Eucalyptus species whereas the lowest mean plant height was that of E. citriodora (100.04 cm). The interactions effects indicate that E. pellita had the highest percent reduction (44%) in height at 120 mM and E. camaldulensis the lowest (30%) from control. Increasing salinity in irrigation water significantly decreased the collar diameter of the plants. At 7 months after initiation of salinity treatments, collar diameter of plants was 9.7 mm in control, whereas with increased treatment of NaCl concentrations (40, 80 and 120 mM), there was successive decrease in collar diameter, i.e. 9.35, 8.59 and 7.81 mm, respectively (Table 1). Among Eucalyptus species, E. camaldulensis recorded the highest collar diameter (10.65 mm) and lowest (6.82 mm) was in case of E. citriodora. Average root length was the highest (47.14 cm) in control and the lowest (22 cm) at 120 mM concentration. The interaction effects indicate that root length was highest in control in E. camaldulensis (45.56 cm) whereas it was lowest (16.33 cm) in E. citriodora at 120 mM salinity level. Total plant length was found significantly different among the species. E. camaldulensis was found to be significantly superior to other species. Variations were found among treatments. In control, greatest (207.21 cm) total plant length was observed and lowest (126.75 cm) was in case of 120 mM NaCl concentration treatment (Table 1). Highest percent reduction (49%) was recorded for E. pellita at 120 mM and lowest (32%) for E. camaldulensis from control. The highest average survival per cent (80.6%) was recorded for E. camaldulensis and lowest (38.3%) for E. citriodora. Among treatments, the highest average survival was recorded in control (94.4%) which decreased to 31.3% at 120 mM of salinity treatment.

Trees productivity is hampered by salinity stress, which is a major abiotic component. Salinity stress is a complex phenomenon that involves osmotic stress, specific ion impact, nutritional deprivation and other factors, affecting several morphological, physiological and biochemical parameters involved in plant growth and development. Plants have developed a variety of mechanisms to deal with the harmful effects of salts. The analysis of variance for different parameters was significant in the current
Table 1. Growth parameters and survival of *Eucalyptus* spp. subjected to various salinity levels

<table>
<thead>
<tr>
<th>Treatments (NaCl, mM)</th>
<th>E. camaldulensis</th>
<th>E. pellita</th>
<th>E. tereticornis</th>
<th>E. citriodora</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant height (cm)</td>
<td>Collar diameter (mm)</td>
<td>Root length (cm)</td>
<td>Total plant length (cm)</td>
<td>Survival (%)</td>
</tr>
<tr>
<td>0</td>
<td>195.78</td>
<td>11.44</td>
<td>45.56</td>
<td>241.33</td>
<td>100.0</td>
</tr>
<tr>
<td>40</td>
<td>162.50</td>
<td>11.16</td>
<td>36.00</td>
<td>198.05</td>
<td>88.9</td>
</tr>
<tr>
<td>80</td>
<td>144.67</td>
<td>10.24</td>
<td>35.67</td>
<td>180.33</td>
<td>77.8</td>
</tr>
<tr>
<td>120</td>
<td>137.33</td>
<td>9.83</td>
<td>27.00</td>
<td>164.33</td>
<td>55.6</td>
</tr>
<tr>
<td>Mean</td>
<td><em>160.07</em></td>
<td>10.65</td>
<td>36.06</td>
<td>195.54</td>
<td>80.6</td>
</tr>
</tbody>
</table>

LSD (P= 0.05): Species × treatments=NS

| 0                     | 11.44           | 55.11       | 22.56           | 222.56        | 100.0 |
| 40                    | 11.16           | 32.83       | 54.89           | 217.17        | 88.9 |
| 80                    | 10.74           | 29.67       | 8.64            | 146.67        | 77.8 |
| 120                   | 9.74            | 8.33        | 7.69            | 114.00        | 55.6 |
| Mean                  | *10.74*         | 8.33        | 7.69            | 114.00        | 55.6 |

LSD (P= 0.05): Species × treatments=NS

| 0                     | 45.56           | 54.89       | 33.00           | 158.50        | 100.0 |
| 40                    | 36.00           | 32.67       | 23.83           | 121.50        | 88.9 |
| 80                    | 35.67           | 28.89       | 20.67           | 111.00        | 77.8 |
| 120                   | 27.00           | 24.67       | 16.33           | 103.00        | 55.6 |
| Mean                  | 36.06           | 35.28       | 23.46           | 123.50        | 80.6 |

LSD (P= 0.05): Species × treatments=6.04

| 0                     | 222.56          | 158.50      | 207.21*        |
| 40                    | 217.17          | 121.50      | 161.07*        |
| 80                    | 146.67          | 111.00      | 145.54*        |
| 120                   | 114.00          | 103.00      | 126.75*        |
| Mean                  | 195.54          | 123.50      | 207.21*        |

LSD (P= 0.05): Species × treatments=16.97

| 0                     | 100.0           | 100.0       | 100.0           | 77.8          | 94.4 |
| 40                    | 88.9            | 66.7        | 79.2            | 44.4          | 69.8 |
| 80                    | 77.8            | 33.3        | 58.3            | 20.1          | 47.4 |
| 120                   | 55.6            | 16.3        | 42.1            | 11.0          | 31.3 |
| Mean                  | 80.6*           | 54.1*       | 69.9*           | 38.3*         |

LSD (P= 0.05): Species × treatments=NS

*Means followed by different superscript letters are significantly different according to L.S.D. test at P=0.05

experiment, indicating the existence of genetic variability among *Eucalyptus* species and differential response of the species to different salt stress levels. Survival at higher salt concentrations with accumulation of sodium shows significant salt tolerance in *Eucalyptus* spp. The stress effect on growth parameters became more pronounced at 120 mM after 7 months of NaCl treatments. Comparably, earlier studies in *Casuarina* (Bassi et al., 2020) and *Eucalyptus* (Nasim et al., 2009; Singh et al., 2023b) reported that with the increase of salinity, the growth of plant height was drastically reduced. This might be due to application of higher concentration of sodium chloride solution in all species which might have led to effect on photosynthetic rate, carbohydrates formation and their accumulation. Both of these factors might cause plant development to be stifled (Mazher et al., 2007). The decrease in collar diameter of salt-stressed plants could be attributed to the formation of excessive salts and the resulting osmotic variations in the cellular level, causing negative
Eucalyptus traits under salt stress

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effects (Silva et al., 2011; Singh et al., 2023a). The present study is in accordance with Alotaibi et al. (2013), in which stem diameter growth was significantly reduced under the highest levels of salt treatment. Increasing the concentration of NaCl in irrigation water reduced root length of Eucalyptus spp. which could be attributed to the fact that salinity reduced plants ability to utilize water transport due to higher osmotic stress, resulting in a decrease in growth rate as well as changes in plant metabolic processes (Munns, 2002). The results are in conformity with findings of El-Juhany et al. (2008) who noticed significant reduction of root length of three Eucalyptus species under saline irrigation conditions. Pulavarty et al. (2016) have reported remarkable reduction in root length in Eucalyptus citriodora as compared to control as the salinity increased (75 mM NaCl). Decreasing total plant length of the Eucalyptus spp. with increasing salinity levels concurs with findings of Gama et al. (2007) and Houimli et al. (2008) who indicated that increasing the concentration of NaCl was accompanied by proportional reductions in plant length. As the salt content increases around the root zone, osmotic stress has a direct impact on plant growth factors (Munns and Tester, 2008).

Physiological parameters

The relative water content (RWC) of the salt treated plants vary significantly at 7 months after initiation of salinity treatments with respect to increase in NaCl concentrations. Its average values among treatments ranged between 77.27% in control to 48.38% in 120 mM NaCl treated plants (Table 2). Among Eucalyptus species, the mean RWC was highest (71.29%) in E. tereticornis and the lowest in E. citriodora (49.65%). Electrolytes leakage (EL) was found to be significant among the species with different treatments. E. pellita had the highest value (53.20%) which was statistically at par with E. citriodora and E. camaldulensis (Table 2). Variations were also found among treatments. In control, lowest value (22.99%) was recorded and the highest value (76.42%) was at 120 mM NaCl concentration. Chlorophyll content was significantly affected with increasing concentration of NaCl (Table 2). The overall chlorophyll content decreased significantly as the salt level increased. E. tereticornis had the highest mean total chlorophyll content (19.17 mg g⁻¹ fresh weight) which was at par with E. camaldulensis whereas the lowest value was found in E. pellita (9.64 mg g⁻¹ fresh weight). Significant differences were also found among treatments. Plants irrigated with normal water had the highest (21.37 mg g⁻¹ fresh weight) chlorophyll content and those irrigated with 120 mM NaCl had the lowest (9.07 mg g⁻¹ fresh weight). Carotenoid values significantly decreased as the NaCl concentrations increased (Table 2). Among treatments, the highest carotenoid content was recorded when plants were irrigated with normal water and the lowest at 120 mM. E. camaldulensis had the highest value (1.074 mg g⁻¹ fresh weight) which was statistically at par with E. tereticornis.

Table 2. Physiological parameters of Eucalyptus species subjected to various salinity levels

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Relative water content (%)</th>
<th>Electrolyte leakage (%)</th>
<th>Chlorophyll content (mg g⁻¹ fresh weight)</th>
<th>Carotenoid content (mg g⁻¹ fresh weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eucalyptus species</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. camaldulensis</td>
<td>65.53ᵇ</td>
<td>50.38ᵃ</td>
<td>17.96ᵃ</td>
<td>1.074ᵃ</td>
</tr>
<tr>
<td>E. pellita</td>
<td>62.21ᵇ</td>
<td>53.20ᵃ</td>
<td>9.64ᵇ</td>
<td>0.528ᵇ</td>
</tr>
<tr>
<td>E. tereticornis</td>
<td>71.29ᵃ</td>
<td>41.42ᵇ</td>
<td>19.17ᵃ</td>
<td>1.043ᵃ</td>
</tr>
<tr>
<td>E. citriodora</td>
<td>49.65ᵇ</td>
<td>51.07ᵃ</td>
<td>11.87ᵇ</td>
<td>0.692ᵇ</td>
</tr>
<tr>
<td><strong>Salinity levels (NaCl, mM)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>77.27ᵃ</td>
<td>22.99ᵇ</td>
<td>21.37ᵇ</td>
<td>1.113ᵇ</td>
</tr>
<tr>
<td>40</td>
<td>65.84ᵇ</td>
<td>40.47ᵇ</td>
<td>15.79ᵇ</td>
<td>0.928ᵇ</td>
</tr>
<tr>
<td>80</td>
<td>57.20ᵇ</td>
<td>56.19ᵇ</td>
<td>12.41ᵇ</td>
<td>0.723ᵇ</td>
</tr>
<tr>
<td>120</td>
<td>48.38ᵈ</td>
<td>76.42ᵃ</td>
<td>9.07ᵃ</td>
<td>0.572ᵈ</td>
</tr>
</tbody>
</table>

*Means followed by different superscript letters are significantly different for Eucalyptus species and salinity levels separately according to L.S.D. test at $P=0.05$
In the present study, decreased RWC with increasing concentration of NaCl in irrigation water corroborate with the results reported by Singh et al. (2011) and El-Juhany et al. (2008). According to Siddique et al. (2000), the ability of tolerant cultivars to absorb more water from the soil and adjust for transpiration is the reason of greater RWC. The exterior solutions of high salt content generated osmotic stress and dehydration at the cellular level, resulting in a drop in RWC (Greensway and Munns, 1980). Pulavarty et al. (2016) reported that increased RWC reflected salt tolerance mechanism in E. citriodora thereby mitigating the toxic ions with an overall contribution in preventing the plant mortality. Increasing NaCl concentration in irrigation water increased EL. The cell membrane is a thin layer of phospholipids that serves as a semi-permeable barrier to solutes. Any stress, particularly ionic stress, damages the cell membrane and allows ions to flow out (Nisha, 2015). In different crops, electrolyte leakage has been described as a useful selection criterion for salt tolerance (Tiwari et al., 2010). The effect of salt tolerance on electrolyte leakage varies greatly between species and cultivars. When salt concentrations are increased, electrolyte leakage is found to increase greater in salt sensitive cultivars than in salt tolerant cultivars (Mansour and Salama, 2004). Total chlorophyll content was severely affected as the salinity level increased from control (21.37 mg g⁻¹ fresh weight) to 120 mM NaCl (9.07 mg g⁻¹ fresh weight) concentrations. In salt-stressed eucalyptus, chlorophyll pigment was reported to be rigorously damaged (Cha-um et al., 2013). Similarly, Pulavarty et al. (2016) reported that chlorophyll content was significantly affected with increasing concentration of NaCl both at 2 and 6 months of treatments duration in E. citriodora. At high salt concentrations, Kumari et al. (2012) also found decrease in total chlorophyll content in Azadirachta indica leaves. Salinity may be causing the degradation of chlorophyll and chlorophyll protein complexes, resulting in a decrease in total chlorophyll (Sheng et al., 2008). Pulavarty et al. (2016) stated that there was no significant variation in carotenoids content under salt treated seedlings and control after 2 months, whereas it significantly decreased in case of salt treated seedlings after 6 months. Reduction of carotenoid content with increased salinity of the soil in Eucalyptus clones, indicating the higher stability of maximum photosystem II (PSII) efficiency at noon in the clones may be due to the photo protection promoted by carotenoids (Andrade et al., 2019). Santos and Silva (2015) emphasized that the degradation of carotenoid pigments interfered in the photo protection exerted by the plants which increased the chances of photo-oxidation under stress conditions.

### Biochemical parameters

The average proline content of leaves increased at higher salt stress level of 120 mM NaCl concentration (20.73 µmole g⁻¹ dry weight) as compared to the control treatment (7.0 µmole g⁻¹ dry weight) (Table 3). E. camaldulensis had accumulated the highest proline content (16.2 µmole g⁻¹ dry weight) which was statistically at par with E. citriodora while the lowest was recorded in E. tereticornis which was at par with E. pellita under salt stress. Increase in proline content was highest (253%) in E. camaldulensis at 120 mM NaCl concentration over control whereas it was lowest (169%) in E. pellita over control. There was significant increase in total soluble sugar content in the NaCl treated plants with increase in NaCl concentration. Total soluble sugar content was highest at 120 mM after 7 months of treatment and minimum in case of control. E. citriodora had accumulated highest total soluble sugar content and lowest for E. tereticornis which was statistically at par with E. pellita and E. camaldulensis (Table 3). The reducing sugar level increased under salt stress in all the Eucalyptus spp. Under salt stress, highest reducing sugar content was in E. citriodora followed by E. pellita which was statistically at par with E. tereticornis and E. camaldulensis.

E. camaldulensis has high salt tolerance ability due to maximum proline accumulation that allows it to withstand high salt concentration in irrigation water. Cha-um et al. (2013) reported that proline levels significantly increased in all Eucalyptus genotypes when plants were exposed to 200 mM NaCl for 14 days. Similar increase in proline concentration in Pistacia atlantica Desf. was found by Benhassaini et al. (2012). Under salt stress,
Proline content in the roots of salt tolerant alfalfa plants quickly doubled, however in salt sensitive plants the response was sluggish (Fougere et al., 1991). Proline is one of the most important osmolytes in salt stressed plants, controlling osmotic potential at the cellular level (Szabados and Savoure, 2009). Plants that are stressed, such as those that are exposed to salt, accumulate proline. In salt tolerant genotypes, the build-up of high levels of proline may be attributed to both higher rate of proline synthesis and a lower magnitude of proline oxidation (Kumar et al., 2003). Salt stress increased the content of soluble sugars in the leaves of all Eucalyptus spp. as salinity levels increased. Shariat and Assareh (2016) also concluded that soluble sugars content increased progressively by increasing the intensity of salt stress. Plants try to mitigate the negative effects of salt stress by accumulating more soluble sugars, which results in an increase in total soluble sugars. Reducing sugar content under this study increased as salinity increased. One of the mechanisms established by plants to overcome salt stress is a large category of organic osmotic solutes comprised of sugars (Gupta and Huang, 2014). The role of reducing sugars (glucose and fructose) in the adaptive mechanism is more debatable, and their accumulation can be harmful from several perspectives (Kerepesi and Galiba, 2000).

Conclusions

The study showed that the growth traits of E. camaldulensis, E. pellita, E. tereticornis and E. citriodora were drastically reduced under salt stress. The relative water content, chlorophyll and carotenoids decreased significantly under salinity stress. Consequently, electrolytes leakage increased significantly under high salt stress treatment. Furthermore, an increase in proline, total soluble sugar and reducing sugar synthesis reflects a salt tolerance mechanism, mitigating the effect of toxic ions and contributing to plant mortality prevention. Results indicate that E. camaldulensis, E. pellita, E. tereticornis and E. citriodora.
**References**


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