GROWTH PERFORMANCE AND STOMATAL BEHAVIOR IN RELATION TO ECOTYPIC ADAPTATIONS IN CYNODON DACTYLON (L.) PERS.

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Abstract

Evolution has great ecological significance in terms of plant morphological and stomatal characteristics that must have been genetically fixed during the long evolutionary period. Impact of environmental conditions on growth and stomatal features of twelve ecotypes of Cynodon dactylon that were collected from ecologically different habitats in the Punjab, Pakistan were evaluated. The collected ecotypes Derawar Fort-saline desert (DF-SD), Muzaffar garh-River bank (M-RB), Khabbeki Lake-hyper saline (KL-HS), Uchchali Lake-hyper saline (UL-HS), Kalar Kahar Lake-saline (KKL-S), Treenus-saline wetland (T-SW), Sahianwala-saline wetland (S-SW), Sahianwala-hyper saline (S-HS), Pakka Anna-hyper saline (PA-HS), Pakka Anna-reclaimed field (PA-RF), Botanic Garden-non saline (BG-NS) and Gatwala-saline semiarid (G-SSA) were grown in controlled environments at University of Agriculture, Faisalabad till their acclimatization to evaluate genetically fixed characteristics. After 6-month growth in soil, the plants were transferred to half-strength Hoagland’s nutrient medium. There was a huge variation in all morphological characteristics recorded during the investigation, which were due to environmental heterogeneity to which these ecotypes were originally adapted. An exclusive feature of the DF-SD ecotypes is the long and numerous roots, and tillering capacity that surpassed all other ecotypes. Leaves per plant were also exceptionally high that may improve the photosynthetic efficiency of the plant. It showed a good potential of overall growth and biomass production. The robust growth was also recorded in the KKL-S ecotypes, and this can be related to the complete dominance of these two ecotypes in their respective habitats. Small stoma were recorded in the three ecotypes (DF-SD, KL-HS and PA-HS), which are of great ecological significance. Stomatal shape, however, is different in different ecotypes, but its contribution towards stress tolerance is still to be investigated.

Key words: Cynodon dactylon, Ecotypes, Stomata, Evolution, Environmental heterogeneity.

Introduction

Geographical distribution of species depend on a specific set of environment that might has fixed during the long evolutionary history (Lowery et al., 2014). These ecotypes have specific structural, functional and geographical variations (Johnson, 2010; Phillips et al., 2015) and these variations was reflected into their morpho-anatomical and physio-biochemical characteristics (Sri-Devi et al., 2012). These adaptive markers have principal importance to study the adaptive mechanism in differentially adapted ecotypes (Hameed et al., 2011). The grasses occupying extreme adverse environmental conditions, which are extremely unfavorable to plant growth and development (Arshad et al., 2008). But against environmental heterogeneity xeromorphic characters develops to reduce water loss as thickness of dermal tissue, decreased stomatal area and density on adaxial leaf surface (Hameed et al., 2013), extensive root system (Hameed & Asrifa, 2008), reduced leaf area (Monteverdi et al., 2008).

A significant proportion of land is covered by grasses that constitutes rangelands all over the world (Kellogg, 2011, Wang et al., 2015). Bermuda grass [Cynodon dactylon (L.) Pers.], which is naturally occur in Indo-Pak subcontinent (Kim et al., 2008), can grow best and get the maximum coverage and growth at 20-25°C. It is stoloniferous, fast growing grass with deep rhizomes and high percentage of seed production. It is extensively planted all over the world as a turf grass (Omezine & Harzallah, 2011).

Cynodon dactylon is extremely drought tolerant and riparian grass that plays a fundamental role in controlling soil erosion by developing deep root and creeping stems (Chen et al., 2015a). Soil-root system expressively correlates to the plant and soil features as plant species (Stokes et al., 2009; Fan & Lai, 2014), root configuration and spreading (Ji et al., 2012; Ghestem et al., 2014).

Stomata are small perforated structures (Hetherington & Woodward, 2003) that act as a vital gate between plant and atmosphere (Nilson & Assmann, 2007). These are strongly influenced by environmental impact (Niu et al., 2008), and key factor in taxonomic delimitation (Babu & Savithramma, 2014). These involve in gaseous interchange (Franks & Farquhar, 2007) and photosynthesis aptitude that ultimately induce or reduce plant growth (Franks et al., 2009). Cynodon dactylon has paracytic type of stomata (Abid et al., 2007) and arranged in parallel rows in the epidermis with silica bodies on the leaf epidermal surface.

The study was focused on the evolution of ecological significance of plant morphological and stomatal characteristics that must have been genetically fixed during the long evolutionary period. Since soil characteristics and environmental factors greatly effect plant growth and stomatal characteristics (Shrivastava & Kumar, 2015), the study was designed to correlate the impact of environmental conditions to growth and stomatal features of differently-adapted ecotypes of C. dactylon all over the Punjab. The main objective of the study was to evaluate ecological response of differently adapted ecotypes of C. dactylon based on morphological and stomatal characteristics.
Material and Methods

Collection sites: Twelve ecotypes of *Cynodon dactylon* were collected from ecologically different habitats in the Punjab, Pakistan (Fig. 1). Selection was based on environmental conditions of the collection site. The selective sites were: DF-SD (Derawar Fort-saline desert, ECE 25.1 dS m⁻¹, Na⁺ 4253.4 mg Kg⁻¹, Cl⁻ 2351.9 mg Kg⁻¹) from the Cholistan desert, soil is sandy to loamy sandy, compact and heavily salt-affected. MG-RB (Muzaffargarh-river bank, ECE 2.9 dS m⁻¹, Na⁺ 320.4 mg Kg⁻¹, Cl⁻ 320.5 mg Kg⁻¹) was collected from non-saline sandy river soil, which was in direct contact with river water. Three ecotypes, KL-HS (Khabbeki Lake-hyper saline, ECE 11.5 dS m⁻¹, Na⁺ 2336.4 mg Kg⁻¹, Cl⁻ 1086.7 mg Kg⁻¹), UL-HS (Ucchali Lake-hyper saline, ECE 19.4 dS m⁻¹, Na⁺ 4035.1 mg Kg⁻¹, Cl⁻ 2021.6 mg Kg⁻¹) and KKL-S (Kalar Kahar Lake-saline, ECE 5.1 dS m⁻¹, Na⁺ 1052.9 mg Kg⁻¹, Cl⁻ 471.7 mg Kg⁻¹) were collected from banks of salt marshes in the Salt Range, which were exposed to saline waters. Two ecotypes were from saline wetlands, T-SW (Treemu-saline wetland, ECE 12.5 dS m⁻¹, Na⁺ 2895.2 mg Kg⁻¹, Cl⁻ 1148.2 mg Kg⁻¹) and S-SW (Sahianwala-saline wetland, ECE 13.3 dS m⁻¹, Na⁺ 2719.7 mg Kg⁻¹, Cl⁻ 1229.7 mg Kg⁻¹), which were collected from saline waterlogged soils. G-SSA (Gatwala-saline semiarid, ECE 19.2 dS m⁻¹, Na⁺ 3946.2 mg Kg⁻¹, Cl⁻ 2015.3 mg Kg⁻¹) and S-SSA (Sahianwala-hyper saline, ECE 4.4 dS m⁻¹, Na⁺ 947.2 mg Kg⁻¹, Cl⁻ 446.8 mg Kg⁻¹) and PA-HS (Pakka Anna-Hyper saline, ECE 6.7 dS m⁻¹, Na⁺ 1320.6 mg Kg⁻¹, Cl⁻ 656.2 mg Kg⁻¹) were collected from dryland salinities, whereas PA-RF (Pakka Anna-reclaimed field, ECE 2.2 dS m⁻¹, Na⁺ 461.7 mg Kg⁻¹, Cl⁻ 232.7 mg Kg⁻¹), where the soil was reclaimed by salt-tolerant species and is now is cultivable for many glycophytic crop species. BG-NS (Gatwala Garden-non saline, ECE 1.0 dS m⁻¹, Na⁺ 81.6 mg Kg⁻¹, Cl⁻ 312.2 mg Kg⁻¹) was collected from the University of Agriculture, Faisalabad and treated as the control.

Soil analysis: Soil from rhizosphere was taken from each habitat to analyze the physico-chemical characteristics at 16 cm depth. The soil extract was used to determine the pH and ECE using pH/EC meter (WTW series InoLab pH/Cond 720). Sodium (Na⁺), potassium (K⁺) and calcium (Ca²⁺) contents were determined with a flame photometer (Model 926; Sherwood Scientific Ltd., Cambridge, UK). Available phosphorus in soil was determined following Bray and Kurtz (1945) method and magnesium (Mg²⁺) was determined by the method of Richards (1954) with an atomic absorption spectrophotometer (Model Analyst 3000; Perkin Elmer, Norwalk, CT).

Morphological parameters: The collected ecotypes were grown in controlled environments at Botanic Garden Research Area in University of Agriculture, Faisalabad till their acclimatization to evaluate genetically fixed characteristics during long evolutionary history. After 6-month growth in soil, the plants were transferred to half-strength Hoagland’s nutrient medium. For dry weight,

plants were oven-dried at 65°C until constant weight was achieved and growth parameters i.e., shoot length (cm), root length (cm), internode length (cm), number of tillers plant⁻¹, number of leaves plant⁻¹, flag leaf area per plant (cm²), number of adventitious roots plant⁻¹, fresh weight (g plant⁻¹) and dry weight (g plant⁻¹) was recorded.

Stomatatal attributes: For the stomatal studies, leaves from the all ecotypes were preserved in formalin acetic alcohol fixative for 48 h and then transferred to 75% solution of ethyl alcohol solution. Permanent slides were prepared by peeled off method (Eckerson, 1908; Weyers & Travis, 1981) then by serial dehydrations in ethanol using Safranin as stain. Photographs were taken by a camera-equipped light microscope (Meiji Techno: MT4300H USA) using an ocular micrometer, which was calibrated with a stage micrometer.

Statistical analysis: The data was analyzed for analysis of variance in completely randomized design with three replications. The data was also subjected to redundancy analysis (RDA) using Conoco 4.5 computer software. The data was also subjected to multivariate cluster analysis

Results

Morpho-agronomic characteristics: Various ecotypes of *Cynodon dactylon* (L.) Pers. from the Punjab region responded differently for morpho-agronomic characteristics in several soil types from differently adapted ecotypes of *C. dactylon*. Plant height was significantly higher in ecotype collected from UL-HS than the second best from KKL-S and KL-HS (Table 1). The smallest plants were recorded from S-SW, BG-NS and PA-RF ecotype. The maximum root length was recorded in DF-SD ecotype, followed by that in UL-HS and KKL-S ecotypes. The minimum value for root length was recorded in the KL-HS ecotype, which was significantly lower than the second minimum from BG-NS. Internode length was the maximum in KKL-S ecotype, followed by the G-SSA ecotype and its minimum was observed in the S-SW ecotype.

The DF-SD ecotype from saline desert showed the maximum of tillers per plant, leaves per plant, number of seminal roots and inflorescence. Tilling capacity in also high in the M-RB and S-SW, whereas leaves per plant in PA-HS and S-HS. Number of roots were relatively higher in MG-RB and G-SSA, while number of inflorescence was also high in KL-HS and UL-HS (Table 1).

Leaf area was the maximum in the ecotype S-HS, which was followed by that in PA-HS. The lowest value of leaf area was recorded in two ecotypes, M-RB and S-SW. Root fresh and dry weights were the maximum in ecotype from KKL-S, closely followed by that in DF-SD and MG-RB. The minimum value for root fresh and dry weights were observed in the UL-HS and PA-RF ecotypes (Table 1).

Stomatal density and size was the maximum in the PA-HS and S-HS ecotypes, while the minimum values for stomatal density and stomatal area were recorded in the PA-HS and T-SW ecotypes (Table 1). Stomatal shape was almost circular in the KL-HS ecotype, whereas the S-SW, KKL-S, PA-HS and BG-NS had broadly elliptic stomata. The DF-SD and PA-RF showed rectangular stomata, while the others has typically elliptic stomata (Fig. 2).
### Fig. 1: Pictorial representation of the collection sites of *Cynodon dactylon* (L.) Pers. from the Punjab, Pakistan.

<table>
<thead>
<tr>
<th>Site Description</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derawar Fort-Saline desert</td>
<td><img src="image1" alt="Derawar Fort-Saline desert" /></td>
</tr>
<tr>
<td>Muzaffargah-River bank</td>
<td><img src="image2" alt="Muzaffargah-River bank" /></td>
</tr>
<tr>
<td>Khabbeki Lake-Hyper saline</td>
<td><img src="image3" alt="Khabbeki Lake-Hyper saline" /></td>
</tr>
<tr>
<td>Uchhali Lake-Hyper saline</td>
<td><img src="image4" alt="Uchhali Lake-Hyper saline" /></td>
</tr>
<tr>
<td>Kalar Kahar Lake-Saline</td>
<td><img src="image5" alt="Kalar Kahar Lake-Saline" /></td>
</tr>
<tr>
<td>Treemu-Saline wetland</td>
<td><img src="image6" alt="Treemu-Saline wetland" /></td>
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<tr>
<td>Sahiwal-Saline-Wetland</td>
<td><img src="image7" alt="Sahiwal-Saline-Wetland" /></td>
</tr>
<tr>
<td>Sahiwal-Saline-Hyper saline</td>
<td><img src="image8" alt="Sahiwal-Saline-Hyper saline" /></td>
</tr>
<tr>
<td>Pakka Anna-Hyper saline</td>
<td><img src="image9" alt="Pakka Anna-Hyper saline" /></td>
</tr>
<tr>
<td>Pakka Anna-Reclaimed field</td>
<td><img src="image10" alt="Pakka Anna-Reclaimed field" /></td>
</tr>
<tr>
<td>Botanic Garden-Non saline</td>
<td><img src="image11" alt="Botanic Garden-Non saline" /></td>
</tr>
<tr>
<td>Ghotwala-Saline Semi-arid</td>
<td><img src="image12" alt="Ghotwala-Saline Semi-arid" /></td>
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</tbody>
</table>

### Fig. 2: Leaf surface view of *Cynodon dactylon* (L.) Pers. ecotypes collected from the Punjab, Pakistan.

<table>
<thead>
<tr>
<th>Site Description</th>
<th>Image</th>
</tr>
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<tbody>
<tr>
<td>Derawar Fort-saline desert</td>
<td><img src="image13" alt="Derawar Fort-saline desert" /></td>
</tr>
<tr>
<td>Muzaffargah-river bank</td>
<td><img src="image14" alt="Muzaffargah-river bank" /></td>
</tr>
<tr>
<td>Khabbeki Lake-hyper saline</td>
<td><img src="image15" alt="Khabbeki Lake-hyper saline" /></td>
</tr>
<tr>
<td>Uchhali Lake-hyper saline</td>
<td><img src="image16" alt="Uchhali Lake-hyper saline" /></td>
</tr>
<tr>
<td>Kalar Kahar Lake-saline</td>
<td><img src="image17" alt="Kalar Kahar Lake-saline" /></td>
</tr>
<tr>
<td>Treemu-saline wetland</td>
<td><img src="image18" alt="Treemu-saline wetland" /></td>
</tr>
<tr>
<td>Sahiwal-Saline-Wetland</td>
<td><img src="image19" alt="Sahiwal-Saline-Wetland" /></td>
</tr>
<tr>
<td>Sahiwal-Saline-Hyper saline</td>
<td><img src="image20" alt="Sahiwal-Saline-Hyper saline" /></td>
</tr>
<tr>
<td>Pakka Anna-hyper saline</td>
<td><img src="image21" alt="Pakka Anna-hyper saline" /></td>
</tr>
<tr>
<td>Pakka Anna-reclaimed field</td>
<td><img src="image22" alt="Pakka Anna-reclaimed field" /></td>
</tr>
<tr>
<td>Botanic Garden-Non saline</td>
<td><img src="image23" alt="Botanic Garden-Non saline" /></td>
</tr>
<tr>
<td>Ghotwala-saline Semi-arid</td>
<td><img src="image24" alt="Ghotwala-saline Semi-arid" /></td>
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</tbody>
</table>
Table 1. Plant growth and stomatal behavior of *Cynodon dactylon* (L.) Pers. ecotypes from selected habitats in the Punjab, Pakistan.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>saline-arid</th>
<th>River water</th>
<th>Salt marshes</th>
<th>Saline wetlands</th>
<th>Dry-land salinity</th>
<th>Reclaimed soil</th>
<th>Non-saline control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DF-SD</td>
<td>M-RB</td>
<td>KL-HS</td>
<td>UL-HS</td>
<td>KKL-S</td>
<td>T-SW</td>
<td>S-SW</td>
</tr>
<tr>
<td>Shoot length (cm)</td>
<td>49.9 bcd</td>
<td>45.7 cde</td>
<td>57.5 abc</td>
<td>69.4 a</td>
<td>62.6 ab</td>
<td>43.1 cde</td>
<td>30.4 e</td>
</tr>
<tr>
<td>Root length (cm)</td>
<td>17.7 a</td>
<td>10.1 b</td>
<td>9.3 b</td>
<td>14.4 ab</td>
<td>14.3 ab</td>
<td>9.3 b</td>
<td>7.6b</td>
</tr>
<tr>
<td>Roots per plant</td>
<td>59.3 a</td>
<td>53.3 b</td>
<td>28.8 e</td>
<td>14.6 g</td>
<td>45.3 c</td>
<td>34.6 d</td>
<td>36.3 d</td>
</tr>
<tr>
<td>Internode length (cm)</td>
<td>3.3 a</td>
<td>4.3 a</td>
<td>4.9a</td>
<td>4.6a</td>
<td>5.9a</td>
<td>4.2a</td>
<td>3.1a</td>
</tr>
<tr>
<td>Tillers per plant</td>
<td>44.3 a</td>
<td>25.4 b</td>
<td>18.6 c</td>
<td>15.1 c</td>
<td>15.0 c</td>
<td>17.6 e</td>
<td>24.7 b</td>
</tr>
<tr>
<td>Leaves per plant</td>
<td>369.1 a</td>
<td>155.5 f</td>
<td>125.8 g</td>
<td>193.2 d</td>
<td>244.5 c</td>
<td>260.1 b</td>
<td>75.0 i</td>
</tr>
<tr>
<td>Single leaf area (cm(^2))</td>
<td>0.26 abc</td>
<td>0.21 c</td>
<td>0.36 abc</td>
<td>0.45 abc</td>
<td>0.35 abc</td>
<td>0.45 abc</td>
<td>0.37 abc</td>
</tr>
<tr>
<td>Total leaf area (cm(^2))</td>
<td>95.9 g</td>
<td>32.5 bc</td>
<td>45.6 d</td>
<td>86.8 f</td>
<td>85.4 f</td>
<td>117.3 g</td>
<td>32.3 bc</td>
</tr>
<tr>
<td>inflorescence per plant</td>
<td>4.0 a</td>
<td>1.6 cd</td>
<td>3.3 ab</td>
<td>2.1 bcd</td>
<td>1.3 cd</td>
<td>1.3 cd</td>
<td>1.1 d</td>
</tr>
<tr>
<td>Root fresh weight (g)</td>
<td>5.4 a</td>
<td>4.3 b</td>
<td>4.8 ab</td>
<td>1.1 e</td>
<td>5.4 a</td>
<td>2.8 cd</td>
<td>3.2 cd</td>
</tr>
<tr>
<td>Root Dry weight (g)</td>
<td>0.91 bc</td>
<td>1.12 b</td>
<td>0.53 cde</td>
<td>0.41 de</td>
<td>1.44 a</td>
<td>0.68 bcde</td>
<td>0.75 bcde</td>
</tr>
<tr>
<td>Shoot fresh weight (g)</td>
<td>7.5 c</td>
<td>3.3 h</td>
<td>4.6 g</td>
<td>8.2 b</td>
<td>10.3 a</td>
<td>5.7 e</td>
<td>5.6 ef</td>
</tr>
<tr>
<td>Shoot dry weight (g)</td>
<td>3.4 a</td>
<td>1.3 d</td>
<td>2.4 bc</td>
<td>3.4 a</td>
<td>3.1 ab</td>
<td>2.6 abc</td>
<td>2.5abc</td>
</tr>
</tbody>
</table>


B-Ellip: Broadly elliptic, Cir: Circular, Ellip: Elliptic, Rect: Rectangular
The other ecotypes clustered into two major groups, one containing 7 ecotypes and the other 4 ecotypes. In the first group, the M-RB ecotypes closely clustered with G-SSA and S-SW, whereas KL- HS with PA- HS and PA-RF with BG-NS. In second cluster, UL- HS closely clustered with S- HS and KKL- S with T-SW.

Dendrogram for stomatal characteristics (Fig. 4) showed isolated behavior for PA- HS, whereas other ecotypes clustered into two major groups. The first group consisted of 9 ecotypes and the second of 2 ecotypes (S- HS and PA- RF). The first group showed 3 sub-clusters, in which DF- SD clustered independently, while KL- HS clustered with BG- NS. Six ecotypes clustered into a separate group, in which UL- HS closely clustered with KKL- S and S- SW with G- SSA.

**Discussion**

*Cynodon dactylon* is a C₄ perennial grass and it is warm season turf grass (Shi et al., 2012) that can acquire a variety of habitats including high salinities (Chen et al., 2015b), waterlogging (Xie et al., 2015; Lukacs et al., 2015), arid and semi-arid regions (Akram et al., 2015; Malik et al., 2015), river and canal beds (Soliman et al., 2015; Chirebvu and Chimbari, 2015. Zwerts et al., 2015), forests (Joubert et al., 2015; Rasool et al., 2015.), high altitudes (Acic et al., 2015; Faizul-Haq et al., 2015), wastelands (Nowak et al., 2016; El-Ghani et al., 2015), grasslands (Radoutou, 2015; Srivastava et al., 2015), etc.

There was a huge variation in all morphological characteristics recorded during the investigation, which were due to environmental heterogeniety to which these ecotypes were originally adapted. Since these ecotypes were evaluated under controlled conditions, therefore, characteristics that are genetically fixed expressed were due to environmental heterogeniety to which these ecotypes were originally adapted. Since these ecotypes were evaluated under controlled conditions, therefore, characteristics that are genetically fixed expressed.

Growth in terms of shoot length (and internode length) was relatively high in ecotypes that were collected from salt marshes (Khabbeki, Ucchali and Kalar Kahar lakes) in the Salt Range. The Salt Range is a unique biome (Ahmad et al., 2012), and therefore it is expected that evolutionary forces acted similarly on the Salt Range ecotypes, and as a result, these populations are relatively taller than the others. The ecotypes that were collected from either no salinity (Botanic Garden) or low salinity (Pakka Anna-reclaimed field) were shorter in length. The ecotypes collected from stressful condition when grown in normal climatic conditions may show stimulated growth (Bita & Gerates, 2013; Hu et al., 2015), whereas those from non-stressed environments responded normally.

An exclusive feature of the DF- SD ecotypes is the long and numerous roots, which is of great ecological significance (Pessarakli, 2015). Environmental conditions in the Cholistan desert are extremely harsh facing multiple stresses like aridity, salinity, heat, nutrient non-availability, etc., and longer roots are capable of extracting water from deeper soil layer (Gao et al., 2016), hence can play a vital role in the survival of the Cholistan ecotype. Generally, the ecotypes from salt marshes also showed longer root than other ecotypes, where the water is hyper-saline, but number of adventitious roots were not as high as was recorded in the Derawar Fort (Cholistan) ecotype. Under such conditions, longer root are very useful that can extract less saline filtered water from deeper soil layers (Hu et al., 2015).
Tillering capacity is the most dominant feature of *C. dactylon* that controls its vegetative propagation and spread along the ground (Mobasheri, 2011; Rangani *et al*., 2016). The Cholistan ecotype surpassed all other ecotypes regarding tillers per plant, almost 2-fold greater than the second maximum. Nutrient availability is restricted in patches in desert soils (Hodge, 2006; He *et al*., 2015), a this kind of vertical spread to longer distance enables a plant to utilize maximum nutrient resources (Irving, 2015).

Leaves per plant were exceptionally high in the DF-SD population, but much smaller in size. Large number of leaves may certainly improves the photosynthetic efficiency of a plant (Weraduwage *et al*., 2015), but smaller leaves may increase water use efficiency by controlling transpiration rate (Medrano *et al*., 2015), which is a vital commodity to survive in harsh saline desert conditions. Treemu saline wetland is expected to fluctuate considerably regarding salinity level, as fresh water from a canal is added seasonally to the saline soil, hence dropping down the salinity level. Number of leaves as well as leaf area per plant were significantly higher in this ecotype.

Inflorescence number was again significantly higher in the DF-SD ecotypes, and this might be due to better growth and tillering in this ecotype. The success of *C. dactylon* in dominating an environmental heterogeneity may be due to a variety of propagation means, i.e., via seeds, suckers, runners or stolons (Rita *et al*., 2012), and this might be the reason of its survival under extremely harsh climatic condition like the Cholistan desert.
Fresh and dry biomass production is a good parameter to judge stress tolerance (Jaleel et al., 2009; Khosroshahi et al., 2014). The DF-SD ecotype showed a good potential of overall growth. The robust growth was also recorded in the KKL-S ecotypes, and this can be related to the complete dominance of these two ecotypes in their respective habitats. Root parameters like length, number, fresh and dry weights has earlier been related with drought and/or physiological drought by Wang and Bugharra (2008) in several Fescue grasses, Xu et al. (2010) in various plants, Talukdar (2013) in lentil and grass pea genotype and Ye et al. (2015) in C. dactylon.

Stomatal parameters like size, number and shape are of great ecological significance (Jian et al., 2012) and extremely important in stress tolerance (Xu & Zhou, 2008; Zheng et al., 2013) Small stomata were recorded in three ecotypes (DF-SD, KL-HS and PA-HS), which can be related to more efficient regulation, as less turgor is required for their opening and closing. Stomatal regulation, in addition to size and shape is also very important for increasing water use efficiency of a plant (Hameed et al., 2002; Lawson & Blatt, 2014). Moreover, stomatal density again improves the photosynthetic efficiency of a plant (Hameed et al., 2002; Lawson & Blatt, 2014). Moreover, stomatal density again improves the photosynthetic efficiency of a plant species, and therefore ecotypes like PA-HS, M-RB and SF-SD can be rated as the better. Stomatal shape, however, is different in different ecotypes, but its contribution towards stress tolerance is still to be investigated.

References


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