

## Effect of Salinity Stress on the Morphology & Physiology of Five Different *Coleus* Species

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### ABSTRACT

The present study aimed at determining the morphological and physiological response of five different *Coleus* species under salinity stress. Salinity is one of the major abiotic stress factor shows negative effect on different agricultural activities. Thus, demands the need of developing salt tolerant plant varieties. *Coleus* is one of the important medicinal plants with several therapeutic properties, but the information related to physiological and morphological response which helps in determining the level of salt tolerance in *Coleus* species has not been reported yet. Study carried out to investigate the effect of different salinity concentrations (100, 200 & 300 mM NaCl) on carbohydrate content, plant growth, leaf area and biomass. Salinity stress significantly reduced the plant growth, leaf water potential (LWP) and relative water content (RWC) in all five *Coleus* species whereas, the content of carbohydrates, water uptake capacity (WUC) and electrolyte leakage (EL) was increased. Among the five different *Coleus* species considered for the present study, *Coleus aromaticus* and *Coleus amboinicus* have shown better tolerance to the salinity stress with respect to their morphology, carbohydrate content, decreased water potentials, increased electrolyte leakage and water uptake capacity. The increased accumulation of carbohydrates with increased salinity suggests that they act either as respiratory substrates or as osmolytes confer salinity stress tolerance.

**Keywords:** Salinity stress, *Coleus*, biomass, carbohydrates, electrical conductivity.

### INTRODUCTION

Salinity stress is one of the most deleterious abiotic stress factors that affect the growth, productivity and physiology of plants. Salinity imposes negative effect on the plant growth by decreasing leaf water potential, inducing morphological and physiological changes, production of reactive oxygen species (ROS), increased osmotic stress, ion toxicity and by altering the biochemical processes<sup>1</sup>. Factors

responsible for salinization are climate, human activities, composition of salt and topography of lands<sup>2</sup>. One of the most common sources of salinity is sodium chloride<sup>3</sup>. Salinity increases the concentration of Na<sup>+</sup> and Cl<sup>-</sup> ions and decreases the concentration of N<sup>+</sup>, PO<sub>4</sub><sup>-3</sup>, K<sup>+</sup>, Mg<sup>+2</sup> and Ca<sup>+2</sup> ions in leaves<sup>4</sup>. The growth of plants is affected by reduction in the uptake of water, lack of nutrients and accumulation of toxic sodium and chloride ions<sup>5</sup>. Sodium is responsible for the dispersion of secondary clay minerals in the



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soil. Chloride is utilized by plants as a micronutrient and as mineral nutrient by many halophytes, but over accumulation of these salts results in low biodiversity and reduced growth and reproduction of salt sensitive plants<sup>6</sup>. The presence of sodium and chloride ions at higher concentrations within the plant cell can also impair the function of enzymes present in the cytosol. The effects of salinity stress are more prominent in arid and semi-arid regions where 25% of the agricultural lands are affected. The two main phases of salinity stress-induced responses of plants are shoot ion independent and ion dependent responses. The first phase occurs within minutes or few days caused by sodium ions leads to closure of stomata and the expansion of leaf is inhibited. During this phase plant water relation is affected by salinity. In second phase, the accumulation of toxic ions takes place particularly in older leaves causing premature senescence, reduced yield and death of plant. Plants have adapted various mechanisms to tolerate the adverse effects of salt stress<sup>7</sup>. Tissue tolerance, shoot ion independent tolerance and ion exclusion are some of the tolerance mechanisms shown by plants to overcome salinity stress. Osmotic adjustment is considered to be one of the most important physiological mechanisms of salinity stress tolerance in plants. The uptake of water, cell turgor and other physiological processes such as cell expansion, photosynthesis and stomatal opening is well controlled with the osmotic adjustment in both the leaves and roots of plants resistant to salts<sup>8</sup>. Although the relationship between salt resistance and osmoregulation is not clear, there is evidence that few plant genotypes exhibit salt tolerance with increasing osmotic adjustment<sup>9</sup>. Plants resistant to salinity stress will grow well by inducing the production of secondary metabolites and avoiding the toxic effects caused by the ion<sup>10</sup>. The other physiological parameters involved in tolerating salinity are transpiration use efficiency, transpiration, production of antioxidants, seed germination, harvest index, early seedling growth, leaf area and maintenance of water status<sup>11</sup>.

The objective of the present study is to analyse the morphological and physiological status of five different *Coleus* species subjected to salinity stress for the identification of the resistant ones. Selection of salt tolerant species is one of the

important strategies to overcome the problem of salinity as well as for increasing the production of plants with medicinal value of which genus *Coleus* is a valuable tool. In order to increase the cultivation of *Coleus* species, it is necessary to understand the effects of salinity on its morphology and physiology. Study carried out to determine the effect of salinity on morphological parameters like plant height, biomass and leaf area of *Coleus*. Relative water content (RWC), leaf water potential (LWP), water uptake capacity (WUC) and relative electrolyte conductivity (REC) are physiological parameters carried out in the present study to understand the plant water relations. The method of relative water content (RWC) in leaves is used to determine the status of plant water reflecting the tissue metabolic activity<sup>12</sup>. The reduced availability of water for the process of cell extension is the result of cell turgor loss indicated with the reduced relative water content<sup>13</sup>. When the plants are under stress, the availability, translocation and absorption of water from soil to roots and leaves is decreased resulting in decreased relative water content and leaf water potential. The electrical conductivity of soil is used to determine whether the soil is partially or strongly saline. Soil is considered to be saline when the electrical conductivity of the soil saturation extract (EC) is 4 dS/m or more and when it exceeds 15 dS/m, soil is considered to be strongly saline<sup>14</sup>.

## MATERIAL AND METHODS

### Collection of plant material and salinity stress treatment

Five *Coleus* species, *aromaticus* (Herbarium No. 21901), *amboinicus* (Herbarium No. 21903), *forskohlii* (Herbarium No. 21905), *zeylanicus* (Herbarium No. 21904) and *barbatus* (Herbarium No. 21906) were propagated in the GITAM University botanical garden in 12 inch pots under 720 minutes natural photoperiod [Irradiance (400-700 nm) of 1600-1800  $\mu$  mols  $m^{-2} s^{-1}$ ] with day/night temperatures of 30°C/23°C with an approximate air humidity of 60%. The pots were arranged in rows 1m apart and the plants were irrigated daily. Three months old plants with uniform growth were selected for this study. *Coleus* plants of all varieties were then separated into four groups namely control (c), mild (100 mM), moderate (200 mM) and severe (300 mM).

Control plants were watered daily and salt-stressed plants were treated with 250 ml of 100, 200 and 300 mM NaCl solutions twice a day for a period of 1 week. Third or fourth leaf from the top of the plant was collected for all the experiments.

**Physiological & Morphological studies**

**Leaf water potential (LWP)**

The leaf water potentials were measured for control, mild, moderate and severe salt stressed plants of all five *Coleus* species using plant

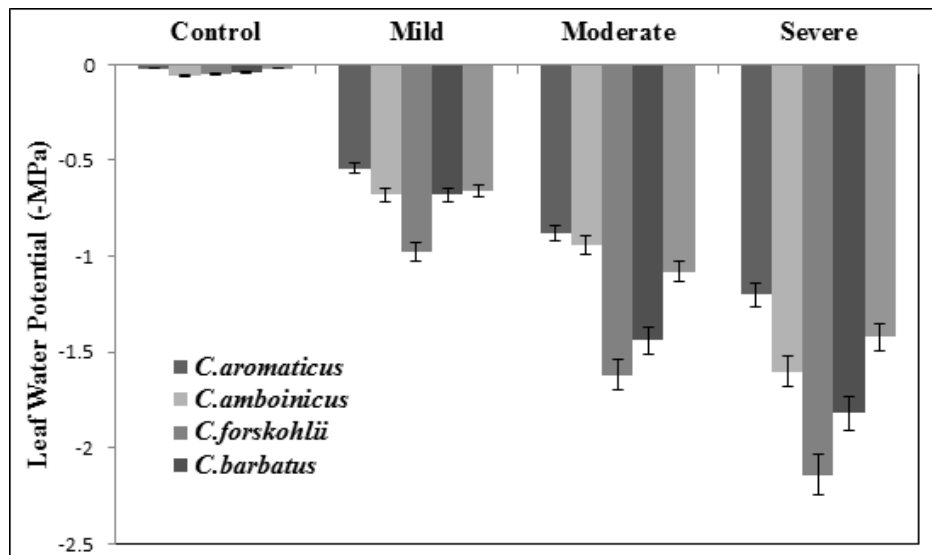


Fig. 1: Leaf water potential of five different *Coleus* species in response to salinity stress. Five independent determinations were made and an average of each point was considered  $\pm$  SE, ( $t_{(4)} = 0.9, p < 0.05$ )

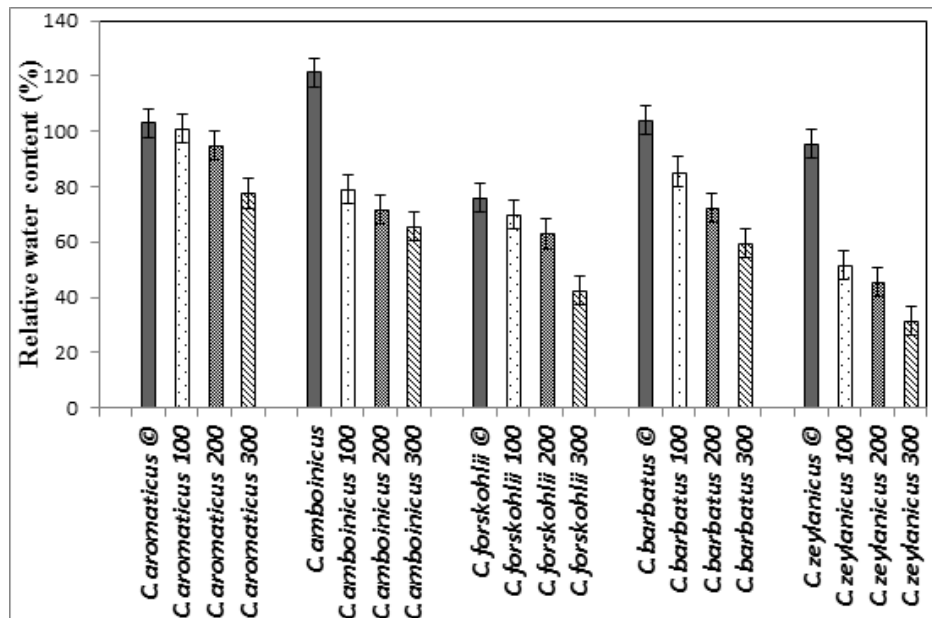


Fig. 2: Relative water content of five different *Coleus* species in response to salinity stress. Five independent determinations were made and an average of each point was considered  $\pm$  SE, ( $t_{(4)} = 10.8, p < 0.5$ )

moisture system SKPM purchased from Skye instruments, UK.

**Relative water content (RWC)**

Relative water content is measured by collecting ten leaf discs from all the species of *Coleus* and immersed into 20 ml of distilled water, left

overnight in a refrigerator. The turgid weight (TW) of leaf discs after drying is taken followed by wrapping leaf pieces in aluminum foil placed in an oven at a temperature of 65°C overnight. The dry weight (DW) of the leaf discs is measured and calculated using the following formula<sup>15</sup>.

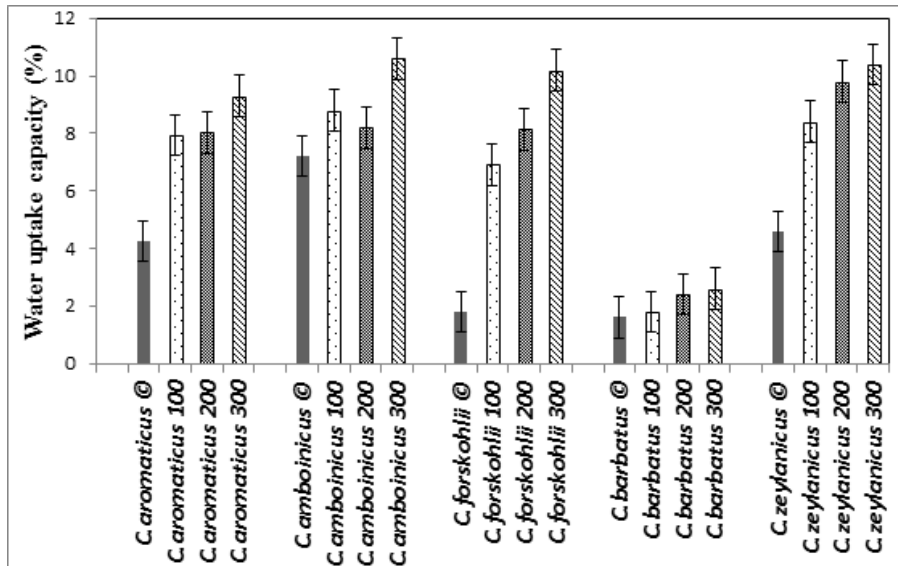


Fig. 3: Water uptake capacity of five different *Coleus* species in response to salinity stress. Five independent determinations were made and an average of each point was considered  $\pm$  SE, ( $t_{(4)} = 6.2, p < 0.5$ )

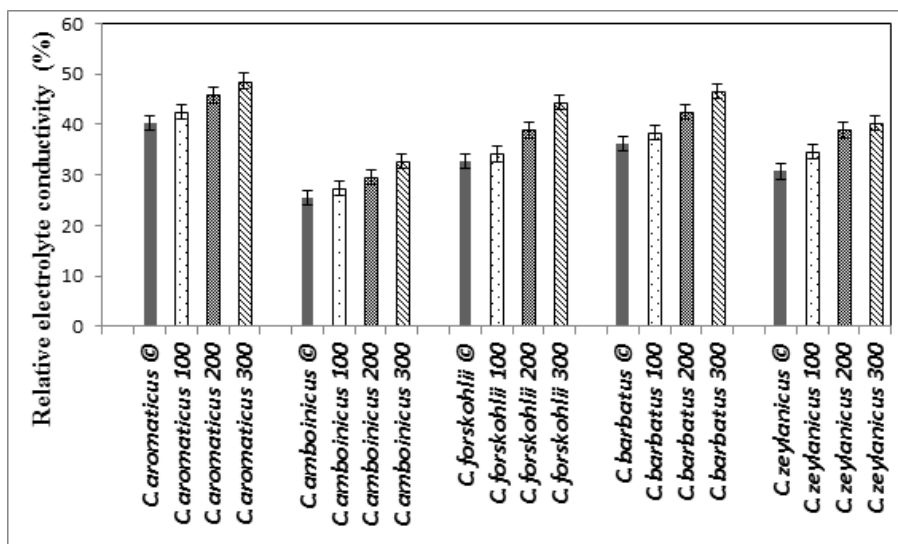


Fig. 4: Relative electrolyte conductivity of five different *Coleus* species in response to salinity stress. Five independent determinations were made and an average of each point was considered  $\pm$  SE, ( $t_{(4)} = 5.8, p < 0.5$ )

$$\text{RWC (\%)} = \frac{\text{FW-DW}}{\text{TW-DW}} \times 100$$

### Water uptake capacity (WUC)

Water uptake capacity was calculated using the following formula according to Sangakkara *et al.*<sup>16</sup>.

$$\text{Water uptake capacity (WUC)} = \text{TW} - \text{FW/DW}$$

### Relative electrolyte conductivity (REC)

Electrolyte conductivity is measured using three leaf discs of 10 mm size, washed thoroughly and placed in a test tube containing 10 ml of distilled water for 30 min. Electrical conductivity of solution (L1) is measured and the tubes were autoclaved. The electrical conductivity was measured again after

the solution had cooled to a temperature of 20°C (L2). REC was calculated according to the following formula<sup>17</sup>.

$$\text{Electrolyte conductivity (\%)} = \frac{\text{L1}}{\text{L2}} \times 100$$

### Electrical conductivity of soil

Soil-water suspension was prepared at a ratio of 1:5, mixed vigorously for 1 hour to dissolve soluble salts. The electrical conductivity of soil is measured by inserting the conductivity meter probe into the solution without disturbing the settled soil using 0.01M KCl as a reference solution.

### Estimation of leaf area, plant height & biomass

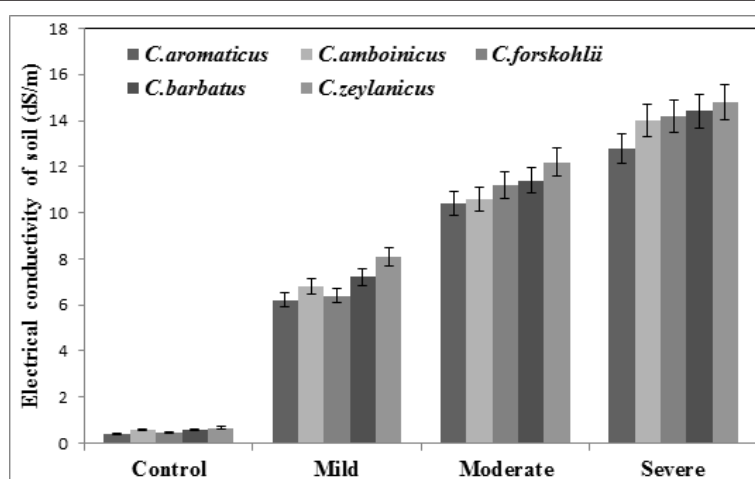
*Coleus* leaf area is measured by graph

**Table 1: Changes in the leaf area, plant height and biomass of five different *Coleus* species in response to salinity stress. Each value is the mean  $\pm$  SE of five independent determinations, (t<sub>(4)</sub> = 3.81, P < 0.05)**

Plant species	Leaf area (Cm <sup>2</sup> )	Plant height (cm)	Biomass (g)
<i>C.aromaticus</i>			
Control	68.12 $\pm$ 2.2	48.8 $\pm$ 1.7	698 $\pm$ 1.32
Mild (100)	66.11 $\pm$ 1.1	42 $\pm$ 2.2	642 $\pm$ 2.2
Moderate (200)	54.62 $\pm$ 1.5	36.17 $\pm$ 1.2	556 $\pm$ 2.1
Severe (300)	48.12 $\pm$ 2.1	32.24 $\pm$ 2.1	520 $\pm$ 1.7
<i>C.amboinicus</i>			
Control	38.27 $\pm$ 1.9	42.44 $\pm$ 2.5	712 $\pm$ 2.3
Mild (100)	32.28 $\pm$ 1.7	40.11 $\pm$ 2.2	668 $\pm$ 1.7
Moderate (200)	24.48 $\pm$ 1.2	32.98 $\pm$ 2.1	618 $\pm$ 1.9
Severe (300)	20.81 $\pm$ 2.1	31.78 $\pm$ 1.9	586 $\pm$ 1.3
<i>C.forskohlii</i>			
Control	72 $\pm$ 1.98	34 $\pm$ 2.11	622 $\pm$ 1.3
Mild (100)	68 $\pm$ 1.24	32 $\pm$ 1.26	584 $\pm$ 1.5
Moderate (200)	42 $\pm$ 1.9	24 $\pm$ 1.46	548 $\pm$ 1.7
Severe (300)	38 $\pm$ 1.7	22 $\pm$ 1.54	518 $\pm$ 2.1
<i>C.barbatus</i>			
Control	38.91 $\pm$ 2.4	49.12 $\pm$ 1.1	612 $\pm$ 1.9
Mild (100)	32.68 $\pm$ 2.3	34.98 $\pm$ 1.5	596 $\pm$ 2.2
Moderate (200)	22.89 $\pm$ 1.7	32.62 $\pm$ 1.8	582 $\pm$ 1.7
Severe (300)	21.22 $\pm$ 1.9	29.88 $\pm$ 1.1	529 $\pm$ 2.1
<i>C.zeylanicus</i>			
Control	44.12 $\pm$ 1.5	44.65 $\pm$ 1.7	582 $\pm$ 2.2
Mild (100)	41.67 $\pm$ 2.1	34.59 $\pm$ 1.2	572 $\pm$ 2.4
Moderate (200)	40.22 $\pm$ 1.82	31.97 $\pm$ 1.57	558 $\pm$ 1.6
Severe (300)	39.99 $\pm$ 1.2	36.66 $\pm$ 1.9	542 $\pm$ 2.1

**Table 2: Estimation of carbohydrate content in five different *Coleus* species subjected to salinity stress. Each value is the mean  $\pm$  SE of five independent determinations, ( $t_{(4)} = 2.8, P < 0.05$ )**

Plant species	Glucose	Fructose	Sucrose	Starch
<i>C.aromaticus</i>				
Control	78 $\pm$ 2.2	72 $\pm$ 2.1	92 $\pm$ 2.6	58 $\pm$ 1.5
Mild (100)	86 $\pm$ 3.2	78 $\pm$ 1.4	82 $\pm$ 1.48	52 $\pm$ 1.2
Moderate (200)	102 $\pm$ 1.8	88 $\pm$ 2.4	98 $\pm$ 2.6	42 $\pm$ 2.2
Severe (300)	112 $\pm$ 1.4	96 $\pm$ 2.2	120 $\pm$ 1.8	38 $\pm$ 2.8
<i>C.amboinicus</i>				
Control	72 $\pm$ 2.1	62 $\pm$ 2.4	96 $\pm$ 1.4	66 $\pm$ 1.1
Mild (100)	78 $\pm$ 2.2	72 $\pm$ 1.6	84 $\pm$ 1.8	54 $\pm$ 2.1
Moderate (200)	98 $\pm$ 3.1	92 $\pm$ 3.2	102 $\pm$ 2.6	46 $\pm$ 1.5
Severe (300)	122 $\pm$ 2.4	108 $\pm$ 1.8	132 $\pm$ 2.8	42 $\pm$ 1.7
<i>C.forskohlii</i>				
Control	64 $\pm$ 2.4	52 $\pm$ 1.3	88 $\pm$ 1.9	38 $\pm$ 1.5
Mild (100)	78 $\pm$ 2.0	68 $\pm$ 1.3	82 $\pm$ 1.7	32 $\pm$ 1.8
Moderate (200)	86 $\pm$ 3.2	82 $\pm$ 2.2	92 $\pm$ 2.2	29 $\pm$ 1.4
Severe (300)	101 $\pm$ 1.6	98 $\pm$ 2.4	122 $\pm$ 2.4	22 $\pm$ 2.6
<i>C.barbatus</i>				
Control	68 $\pm$ 2.6	54 $\pm$ 1.9	88 $\pm$ 1.3	32 $\pm$ 1.8
Mild (100)	84 $\pm$ 2.2	76 $\pm$ 2.1	78 $\pm$ 1.6	28 $\pm$ 2.2
Moderate (200)	92 $\pm$ 1.8	88 $\pm$ 1.7	89 $\pm$ 1.9	22 $\pm$ 2.3
Severe (300)	108 $\pm$ 2.6	102 $\pm$ 1.4	118 $\pm$ 2.2	12 $\pm$ 1.7
<i>C.zeylanicus</i>				
Control	62 $\pm$ 2.1	42 $\pm$ 1.7	82 $\pm$ 2.2	38 $\pm$ 1.8
Mild (100)	72 $\pm$ 2.1	58 $\pm$ 2.1	74 $\pm$ 1.9	28 $\pm$ 1.9
Moderate (200)	80 $\pm$ 1.8	76 $\pm$ 2.7	88 $\pm$ 1.5	22 $\pm$ 2.1
Severe (300)	96 $\pm$ 2.8	88 $\pm$ 1.8	112 $\pm$ 1.4	20 $\pm$ 2.3



**Fig. 5: Soil electrical conductivity of five different *Coleus* species in response to salinity stress. Five independent determinations were made and an average of each point was considered  $\pm$  SE, ( $t_{(4)} = 3.1, p < 0.5$ )**

paper method according to Pandey and Singh<sup>18</sup>. Plant height is measured in centimeters and the biomass measured in grams per fresh weight using weighing balance.

#### Estimation of carbohydrates

The content of carbohydrates; glucose and fructose were determined according to Ashwell *et al.*<sup>19</sup> and Dubois *et al.*<sup>20</sup>. The extracts were prepared by homogenizing the 0.5 grams of *Coleus* leaf tissue in 80% ethanol followed by centrifugation for 10 min at 5000 rpm. 5 ml of anthrone reagent is added to 1 ml of supernatant, incubated for 30 min using water bath and the absorbance was measured at 620 nm for the estimation of glucose. The carbohydrate fructose was estimated by adding 1 ml of resorcinol reagent to 2 ml of extract and by measuring the absorbance at 520 nm after 10 min of incubation. The contents of sucrose and starch were estimated according to Ramachandra Reddy *et al.*<sup>21</sup>.

#### Statistical analysis

Data were analyzed using ANOVA statistical program. Mean  $\pm$  SD values calculated for five samples in each group and the significance of the data was tested using student's *t* test ( $P < 0.05$ ).

### RESULTS AND DISCUSSION

In the present study, the leaf area, plant height, biomass, carbohydrate assay and the physiological parameters such as leaf water potential, relative water content, water uptake capacity, electrolyte conductivity of soil and relative electrolyte conductivity were studied in five different species of *coleus* during salinity stress. Relative water content and leaf water potentials were decreased in all the *Coleus* species subjected to salinity stress (Figure 1 & 2), whereas water uptake capacity and electrolyte leakage levels increased with increasing NaCl concentrations (Figure 3 & 4). The leaf water potentials decreased from -0.02 to -1.2 MPa in *Coleus aromaticus*, -0.06 to -1.6 MPa in *Coleus amboinicus*, -0.05 to -2.14 MPa in *Coleus forskohlii*, -0.04 to -1.82 MPa in *Coleus barbatus* and -0.02 to -1.42 MPa in *Coleus zeylanicus*. The relative water content of five different *Coleus* species were decreased from 103% to 77.6% in *Coleus aromaticus*, 121% to 65.5% in *Coleus amboinicus*, 75% to 48% in *Coleus forskohlii*, 104% to 59% in

*Coleus barbatus* and 95% to 31% in *C. zeylanicus*. However, the relative water content was high in *Coleus aromaticus* and *Coleus amboinicus* during both control and salinity stress conditions. The results of decreased leaf relative water content with the increased levels of stress were reported<sup>22</sup>. Similar results were reported in *Rosmarinus officinalis* when grown under salinity stress<sup>23</sup>. The decrease in relative water content could be due to non-availability of water near root zone and loss of water by transpiration. Electrical conductivity is used to measure the amount of dissolved material or salts from an aqueous solution. The higher electrical conductivity (EC) is due to the presence of higher dissolved salts in soil sample. The increase in the soil electrical conductivity with increased salt treatment compared to control soil was observed in the study (Figure 5). The EC values recorded above 4 dS/m in mild, moderate and severe salt treated soil samples indicate that the water is not suitable for agriculture purposes and the soil is not suitable to support the growth of plants.

The decreased plant growth indicated by the reduced leaf area, plant height and biomass in five *Coleus* species subjected to salinity stress was observed and the results were depicted in Table 1. During salinity stress, plant growth is reduced due to several physiological responses such as changes in the water level, photosynthetic efficiency, carbon utilization and allocation. The decreased plant growth with reduced dry weight was reported in *Andrographis paniculata* Nees. seedlings subjected to salinity stress<sup>24</sup>.

Salt tolerant plants exhibit the mechanism of ion compartment in vacuoles, salt resistance at genetic level and by the accumulation of compatible solutes in the cytoplasm<sup>25</sup>. The increased accumulation of carbohydrates glucose, sucrose, fructose and decrease in the content of starch with increased salinity was observed in all the five species of *Coleus* indicating the plant tolerance to stress (Table 2). To carry out the process of glycolysis and the mechanism of crassulacean acid metabolism (CAM) which involves the transport of intermediate compounds across the membrane and the involvement of starch degrading enzymes degrades the existing starch and utilize it as a source of malate. The changes in the content of starch for



regeneration of phosphoenol pyruvate were reported in several CAM plants<sup>26</sup>. The increased content of soluble sugars with increased salinity was observed in the leaves of *Echium amoenum*<sup>27</sup>, tomato<sup>28</sup> and in barley<sup>29</sup>. The reduction in the biomass of two safflower cultivars namely *Carthamus tinctorius* L. TSF1 and SM; with increased accumulation of soluble sugars and amino acids to overcome stress was reported<sup>30</sup>. The reduced growth and dry weight in response to salinity was reported in several plant species like *Zea mays*, *Hordeum vulgare*, *Gossypium hirsutum* and *Plantago ovate*<sup>31,32,33,34</sup>. The decreased plant growth, height and leaf area during salinity stress is due to the accumulation of toxic ions and less availability of water. In order to avoid the harsh effects of salinity stress, the leaf area will be decreased and the mechanism of osmotic adjustment is brought about by the accumulation of carbohydrates in tissues. The sugars or carbohydrates act either as respiratory substrates or as osmolytes confer salinity stress tolerance. The higher accumulation of carbohydrates during salinity stress also favors the accumulation of an important osmolyte proline. Similar study carried out on other medicinally important CAM plant *Aloe vera* showed reduced growth and yield in terms of decreased leaf number, leaf thickness and plant height; enhanced carbohydrate and proline content under severe conditions of salinity stress<sup>35</sup>. Plants with medicinal value have been used for centuries as herbal medicine to treat diseases<sup>36</sup> and to overcome the usage of synthetic drugs due to their side effects and toxicity. At present only few medicinal plants were cultivated for commercial purposes. *Coleus* is one of the medicinal plants with many therapeutic properties. Hence, there is a need to cultivate this medicinal plant as it is capable of growing under stress conditions. Salinity is one of the major abiotic stress factors affecting medicinal plants<sup>37</sup>. It is evident that salinity interferes with gas exchange during moderate and severe salt stress levels thereby decreases the rate of photosynthesis<sup>38</sup>. The immediate effect of salinity is decrease in stomatal conductance followed by reduced respiration rate and CO<sub>2</sub> assimilation. Earlier, many researchers have reported the translocation of assimilates and the reduced rate of photosynthesis during salinity stress depends mainly upon the species and concentration of salt<sup>39</sup>. By studying the role of plants when subjected to stress, it is possible to know about their metabolic pathways and the function

of enzymes involved. The mechanism of sensitivity and tolerance to stress in plants is not fully known due to complexity of mechanisms involved<sup>40</sup>. Plant water status is affected during salinity stress due to toxic ions which limits the availability of water; major reason for growth reduction in plants as water is being utilized by plants as a solvent and transport medium for their biological activities. The level of tolerance under stress can be evaluated by measuring relative leaf water content which is an integrative index of plant water status. The sensitivity of plants to dehydration is also indicated by relative leaf water content<sup>41</sup>. Accumulation of salts at root zone decreases leaf water potential preventing the absorption of nutrients and water by plants. The water status of plant gets decreased due to the conditions of physiological drought experienced by plants when subjected to salinity stress<sup>7,42</sup>. The growth of plants is affected initially due to decrease in the soil water potential which ultimately leads to the death of plant due to rapid increase in the concentration of salts in the cytoplasm<sup>43</sup>. It was reported that the over accumulation of salts leads to the death of older leaves and the supply of carbohydrates and growth hormones to the other regions of plant is decreased thereby preventing the growth of plant<sup>44</sup>. The enzyme phosphoenolpyruvate carboxylase gets induced by salinity stress and the advantage with the CAM plants is increased water uptake efficiency as the stomata closes during day time and opens at night minimizing the water loss.

Plants acquire resistance to stress through water influx, accumulation of compatible solutes and maintenance of nutrients by potential gradient<sup>45</sup>. The cell membrane acts as a semi-permeable barrier for the transport of solutes but the presence of excess salts leads to the damage of membrane and leakage of ions from cell<sup>46</sup>. The more leakage of electrolytes results in higher conductivity. In our present study a significant decline in the leaf water potential and relative water content was observed in all the five species of *coleus* subjected to salinity stress compared with the non-stressed plants. Electrolytic leakage also called as relative electrolyte conductivity is higher in *coleus* species at severe conditions of salinity stress compared with controls. The relative electrolyte conductivity increased from 40.42% to 48.63% in *C.aromaticus*, 25.6% to 32.68% in *C.amboinicus*, 32.7% to 44.45% in *C.forskohlii*,



36.25% to 46.52% in *C. barbatus* and 30.7% to 40.37% in *C. zeylanicus*. The decreased leaf water potential and increased electrolyte leakage with increased salinity was reported in two cultivars of *Brassica juncea* Czern and Coss varieties (Varuna and RH-30). The electrolyte leakage increased by 26.7% and 32.3% in Varuna and RH-30 compared to controls with an increase in the concentration of NaCl<sup>47</sup>. A significant decrease in the relative water content and increase in the electrolyte leakage was also observed in the medicinal plant Henna (*Lawsonia inermis*) with the increased levels of salinity from 0 to -6 bar<sup>48</sup>. Water uptake capacity is determined by the ability of plant to utilize water is measured in terms of units per dry weight in relation to turgid weight. The increase in the water uptake capacity was observed in *C. aromaticus* from 4.25% to 9.3%, 7.2% to 10.6% in *C. amboinicus*, 1.8% to 10.19% in *C. forskohlii*, 1.6% to 2.6% in *C. barbatus* and 4.6% to 10.4% in *C. zeylanicus* species during salinity stress. The increase in the water uptake capacity (WUC) was reported in wheat cultivars under salinity stress<sup>49</sup>.

## CONCLUSIONS

From the above results, it can be concluded that the study of morphological and physiological parameters is used to determine the response of *Coleus* plants to salinity stress. All *Coleus* species have shown a decrease in their growth and physiology during their exposure to the salinity stress. However, the *Coleus aromaticus* and *Coleus amboinicus* have shown better tolerance to the salinity stress with respect to their morphology, carbohydrate content, decreased water potentials, increased electrolyte leakage and water uptake capacity.

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