Journal of Biological and Agricultural Advancements (JBAA) (2024). 2(2), 64-72
https://journalbaa.com/ ISSN: 3007-2999 (Online)

Research Article Open Access

Salinity Induced Changes in Biomass Partitioning and Physiological and Biochemical Traits in *Syzygium cumini*

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ABSTRACT Soil salinity reduces crop yields and ultimately reduces crop productivity in salt-affected areas, posing a global threat to global agriculture. The current study focused on the salt stress tolerance mechanism in seedlings of *Syzygium cumini* and its effect on biomass production and plant physiology. A pot experiment was conducted and the seedlings were taken from the forest nursery and placed into the earthen pots. These seedlings were exposed to six salt treatments such as T_1 (control), T_2 (4 dSm^{-1}), T_3 (8 dSm^{-1}), T_4 (12 dSm^{-1}), T_5 (16 dSm^{-1}) and T_6 (20 dSm^{-1}) for 6 months. There were four replicates per treatment and a total of 24 plants were examined. The results showed that there was significant difference in growth and physiology of *Syzygium cumini* under different level of salt stress. The fresh and dry weights of shoots and roots were greatly reduced due to the increase in salt concentrations. The reduction in the amount of chlorophyll contents in the leaves was correlated with these changes. The maximum Chl a, Chl b and total Chl contents were 0.7033 mg g^{-1} FW, 0.9096 mg g^{-1} FW, 1.5007 mg g^{-1} FW in T_1 (control) while the minimum Chl a, Chl b and total Chl contents were 0.2993 mg g^{-1} FW, 0.5132 mg g^{-1} FW, 0.8737 mg g^{-1} FW in T_6 (20 dSm^{-1}) respectively. However, in the case of SOD, POD and CAT the maximum activity 3.51 U mg^{-1} protein, 11.98 U mg^{-1} protein, 5.693 U mg^{-1} protein was recorded in T_6 (Control) while the minimum activity 0.7876 U mg^{-1} protein, 37.61 U mg^{-1} protein, 1.692 U mg^{-1} protein was recorded in T_1 (control). Overall the results showed that the *Syzygium cumini* showed stunted growth with the increase of salt stress. The obtained findings will be helpful for future soil reclamation projects.

***Keywords**; Biomass; Agriculture; Salinity; Sustainability; Traits*

To cite this article: Bibi, Z., Khan, T.H., Sabir, M.A., Shahzad, M., Shaheen, H.M.F., Saeed, A. (2024). Salinity Induced Changes in Biomass Partitioning and Physiological and Biochemical Traits in *Syzygium cumini*. *Journal of Biological and Agricultural Advancements*, 2(2), 64-72.

Article History: Received: 22 June, 2024**; Accepted**: 28 July 2024, **Published Online**: 31 August 2024

INTRODUCTION High salinity makes it more challenging for plants to receive water through their roots from the soil because it creates an osmotic imbalance. Both the sodium ion (Na+) and the chloride ion (Cl) accumulate as a result of the cytosol's detrimental salinity (Dong, 2012). These ions build up and disrupt the non-covalent interactions between amino acids (Bordenave et al., 2014), which lowers the concentration of cations like calcium (Ca2+) and potassium (K+) (Asif et al., 2023). The K+ and Na+ equilibrium under the salt factor is crucial for plant development and growth. Salinity disrupts the K+-Na+ interaction, which results in a K+ shortage (Aminullah et al., 2023). Potassium ions are essential for a variety of physiological processes, including enzyme activation tropisms, regulating membrane turgidity, stomatal movement, and osmotic pressure management. K+ and Na+ equilibrium under the salt factor is crucial for plant development and growth. Salinity disrupts the K+-Na+ interaction, which results in a K+ shortage (Khan et al., 2021). A greater K+/Na+ ratio in leaves is seen as a salt-tolerant indication.

Calcium (Ca2+) ingredient under the salt factor depends on the physiology of the plant and the specific organs as well as its length. According to certain research, Ca2+ regulates Na+ inflow through nonselective ion channels, which may contribute to salt toxicity (Assaha et al., 2017).

By generating an excessive amount of reactive oxygen species (ROS), such as superoxide radicals (O2), hydroxyl radicals (OH), and hydrogen peroxide (H2O2), high salinity also contributes to oxidative stress (Choudhury et al., 2013). Numerous cellular damages, including those to nucleic acids, proteins, as well as membrane lipids, are brought on by these reactive species accumulations. Malondialdehyde (MDA) is produced as a byproduct of membrane lipid peroxidation, which is among the most harmful impacts of antioxidant stress (Bhattacharjee, 2014). MDA a lipid peroxidation biomarker, can be used to identify oxidative stress caused by salinity. Salinity generates an imbalance between the activity of antioxidants quenching ROS and their synthesis, leading to antioxidant stress that damages plants. The growth and development of plants, as well as the activity of enzymes, the growth of seedlings, and the germination of seeds, are all severely impacted by salinity stress, according to a number of recent studies (Khalid et al., 2019). Additionally, salinity impairs the hormone supply for developing tissues and photosynthetic assimilations Na+ ions cannot be components of an enzyme as cofactors, whereas K+ ions. A decrease in the rate of CO2 uptake is one observable response of plants to salinity. Both stomatal and non-stomatal limits in photosynthesis are impacted by salinity (Sarabi et al., 2019).

Numerous studies have shown that salt-tolerant species can be divided into groups based on physiological factors including chlorophyll concentration and fluorescence. If so one of the physiological measurements is net photosynthetic rate (NPR). indicators that could be considered as candidates because it is an easy, quick, and sensitive way to calculate the salt tolerance index (Cha-Um & Kirdmanee, 2008). One of the key environmental hazards to land productivity is soil salinity, which also limits the provision of important ecosystem services related to natural resources. Approximately 125 million hectares of land are currently contaminated by salt in various parts of the world, making up about one-fifth of all irrigated land worldwide. Saline soils arise as a result of poor waterlogging, drainage, and the use of subpar irrigation with groundwater, and they are primarily prevalent in dry and semi-arid areas. According to Shrivastava and Kumar (Shrivastava & Kumar, 2015), an international problem that impacts about Significantly, 20% of the land is irrigated. lowers agricultural output. The physiological responses of a plant to salinity are usually intricate and versatile, which makes it problematic to arrange as well as analyze experiments

The restriction of leaf expansion and stomatal closure are two early salinity effects on water relations that can have a big influence (Hernández & Almansa, 2002). The second stage, the ion dependent response to salinity, occurs over a longer time period (days to weeks), and it entails the accumulation of dangerous quantities of ions in the shoot. Particularly in leafy debris. This causes leaves to senesce too soon. and, in the end, lower yield or even plant death. Plants have a number of physiological and biochemical strategies to thrive in soils with high salt concentrations. biochemical responses. According to the information that is now available, diverse abiotic stresses cause different plant species to express a number of similar stress responsive proteins. According to Gupta et al. (Gupta & Huang, 2014), A total of 2171 proteins, which are either upregulated or downregulated in response to salinity stress, have been discovered and described as salt-responsive proteins from 34 different plant species. Based on gene ontology, BLAST alignment, and unpublished data, 14 functional categories can be developed for salt-responsive proteins.

Salinity stress has been linked to decreased plant development, according to a number of researchers (Zhang et al., 2016). But the tolerance to salinity varies between species, cultivars, and the several measured aspects of plant growth. For instance, scientists discovered revealed at 50% seawater, Rhizosphere mucronata plants grew most optimally, and that their growth slowed as the salinity rose. Previously scientists (Aziz & Khan, 2001) discovered whereas it declined at high salinities (100 and 200 mM NaCl), total plant weight increased at low salinities (50 mM NaCl). The fresh and dried mass of the leaves and roots in the sugar beetroot leaf area was significantly decreased at 200 mM NaCl. Less of an impact was felt on the number of 36 leaves. When working with sultana vines, it became clear that photo assimilates were partitioned in favour of the roots since shoots saw a bigger reduction in dry matter accumulation than roots did, especially at high NaCl concentrations. They hypothesized that the roots' improved capacity for osmotic adjustment under stress may be the cause of the observed outcomes (Zhang et al., 2016).

The majority of the water on Earth has a sodium chloride content of 30 g per liter. As a result, the Earth may become a very salty planet. Salt stressors reduce plant biomass while negatively affecting plant form, function, and homeostasis. High soil salinity can significantly hinder seed germination and seedling growth due to the combined effects of high osmotic potential and specific ion toxicity. Plant metabolism is negatively affected by salt stress, which drastically lowers productivity (Khalid et al., 2019; Saeed et al., 2024; Zeng et al., 2024). Plants are impacted by salinity in a variety of ways. For instance, the presence of salt in the soil solution makes it more difficult for the roots to obtain water, and salt that has been stored inside the plant might eventually reach dangerous amounts in numerous plant tissues. By creating an osmotic potential outside the seed that hinders water absorption or by the toxic effects of Na+ and Cl-, salt has a deleterious impact on the germination of many crop seeds (Bhattacharjee, 2014; Li et al., 2024; Mushtaq et al.,2024; Rashid et al., 2024).

As a result, SOD, CAT, GPX, APX, and GR are among the ROS-scavenging proteins that are expressed in plant roots. shoot proteome (Gupta & Huang, 2014). Other proteins implicated in cytoskeleton stability, protein synthesis, processing, turnover, and degradation have been found in numerous investigations. The number of proteins involved in the production of chlorophyll appears to be declining generally. in photosynthetic processes, but a greater involvement of proteins in light-dependent processes. several of the discovered proteins point to a universal pathway through which plants respond to stress. Less frequently found are

proteins that belong to the categories of cell structure, trafficking, transport, and signaling (Ali et al., 2024; Ali et al., 2024; Barkla et al., 2013; Khan, 2024).

Higher plants have a remarkable ability to produce a large range of metabolites with different chemical complexities and biological functions that are essential for lowering stress. Polyols like sorbitol with mannitol, dimethyl sulfonium Plant metabolites that contribute to salinity tolerance include glycine betaine carbohydrates like sucrose, trehalose, and fructans as well as amino acids like proline that serve as osmolytes (Ahmed et al., 2024a; Ahmed et al., 2024b; Ahmed et al., 2024c; Sing et al., 2015). When under salinity stress, plants exhibit a rise in the concentration of these osmolytes, which significantly contributes to stress reduction.

This species is a broadleaf tree with a heavily foliated crown and a height of 15 meters. The fruit harvest begins nine to ten years after planting. Fruit matures after flowering and grows gigantically in up to three months. A large variety of species can be obtained through bee pollination (Cha-Um & Kirdmanee, 2008; Gull et al., 2019; Shrivastava & Kumar, 2015). The fruit has a berry-like physical appearance with a purple mesocarp, an oval, succulent, meaty, and purplish-black pericarp, and only one seed inside. Due to the fruit's high concentration of tannins, phenolic compounds, and organic acids, it has a unique flavor. Fruit begins to ripen between June and July in northern Asia and between December and February in Brazil (Assaha et al., 2017; Khan et al., 2021). Additionally, major elements like potassium and magnesium are found in their fruits and are good for human health (Seraglio et al., 2018). Because they have culinary and therapeutic uses, species of the Syzygieae genus have been determined to have significant economic power. Syzygium cumini (L.) contains bioactive chemicals, natural nutrients, and antioxidants employed as raw materials in the pharmaceutical and food industries (Ahmed et al., 2022; Rashid et al., 2022; Rashid et al., 2022; Seraglio et al., 2018). The current study aimed to Analyzing the effect of salt stress in seedlings of Syzygium cumini. Evaluating growth potential and biomass production in Syzygium cumini against salinity.

MATERIAL AND METHODS

The pot experiment was completed in Forest Nursery and Experimental Area, Institute of Forest Sciences, The Islamia University of Bahawalpur Baghdad-ul-Jadeed Campus. Bahawalpur has a hot environment with high evaporation rates, low relative humidity, infrequent rainfall, and strong summer winds. Annual rainfall is between 90 and 200 mm, with temperatures ranging from 20℃ to 50℃

Experimental layout and treatment applications

Syzygium cumini plants that have been growing for six months as seedlings are taken from the forest nursery. In November 2022, plants are transplanted into pots measuring 13 x 17 cm and holding soil. All plants are identical in terms of their size, age, health, and growth conditions. Both kinds of plant pots are filled with water after transplantation and kept in a natural environment. There were six treatments and four replicates such as T1 (control), T2 (4 dSm-1), T3 (8 dSm-1), T4 (12 dSm-1), T5 (16 dSm-1) and T6 (20 dSm-1) for 6 months. Against salinity stress following parameters were recorded to check the potential of growth of Syzygium cumini such as growth parameters, photosynthetic parameters and biochemical parameters.

Growth parameters

The stem diameter (mm) of Syzygium cumini is measured at the collar point with the help of a digital caliper, which is marked beforehand. At the collar point, two readings are taken to cover circumferential variability from diagonal to each other, and by this method for all individuals mean diameter is calculated. Plant height (cm) of Syzygium cumini is measured with the help of measuring tape of the entire individual from collar point to apex. Two times all these activities are performed firstly on seedling establish and lastly before harvesting. After harvesting the plants shoot as well as root sections of Syzygium cumini by using weighting balance (Electronic Scale JJ3000B) are immediately weighted by placing them into paper bags. By doing this all samples of Syzygium cumini are placed at 74°C in heating Days were spent using an oven (Thermal Electric Thermostat Drying Oven DGH - 9202 series). The dry weight of all these samples is recorded after removing them from the heating oven.

Biomass partitioning in two types is divided one is root biomass other is shoot biomass. Shoot biomass is measured by using following formula:

Shoot biomass (%) = Shoot dry biomass/ total biomass x 100

Root biomass is measured by using following formula:

Root biomass (%) = Root dry biomass/ total biomass x 100

Then total biomass is measured by using given formula:

Total biomass = Shoot dry biomass + Root dry biomass

Photosynthetic parameters

Chlorophyll and carotenoid contents are measured by using (Aminot & Rey, 2001; Arnon, 1949) methods. In this method leaf discs 0.5g is mixed with 10 ml 80% acetone at 10℃ overnight and then at 14000 rpm centrifuged for 5 minutes. On spectrophotometer (PG, T60U) absorbance pf supernatant is measured at 645,652,663 and 480 nm. Chlorophyll contents are quantified by using given formula:

Chla (mg g^{-1} FW) = [12.7(OD663)-2.69(OD645)] × v/1000 × w

Chlb (mg g^{-1} FW) = [22.9(OD645)-4.68(OD663)] × v/1000 × w

Chla+b (mg g^{-1}FW) = [20.2(OD645)-8.02(OD663)] ×v/1000 × w

Carotenoid contents are quantified by using given formula:

Carotenoids (mg g-1 FW) = Acar/Emx100

Here

V= Volume of sample extract and W= Weight of the sample

Acar = (OD480) + 0.114(OD645); Emax100 cm =2500

Biochemical parameters

According to Liu and Huang (2000) method Peroxidase (POD) activity is measured. In this method POD solution is prepared which containing Guaiacol 20 mM. 40 mM H2O2, 50 mM phosphate buffer (pH 5), and 0.1 ml of the enzyme extract. By using spectrophotometer at 470nm frequency changes in absorbance of reaction solution are measured. Peroxidase activity one unit is defined as “An absorbance changes of 0.01 units per minutes”. Each enzyme activity is expressed on protein basis. The ability of Superoxide Dismutase (SOD) to prevent the photo

reduction of Nitroblue Tetrazolium (NBT) is assessed using the (Giannopolitis & Ries, 1977) method to evaluate SOD activity. 0.015g of NBT is present in 17.5 ml of distilled water and 0.222g of methionine is present in 15 ml of distilled water in the superoxide dismutase determination reaction solution. In 17.5 ml of distilled water, combine 0.0132g of riboflavin, 0.2 molar buffer, and 0.0375g of Triton-X. Reaction solution containing tube before adding riboflavin is placed under UV lamp for 15 minutes. With the help of spectrophotometer at 560 nm absorbance of solution is measured. Superoxide Dismutase (SOD) activity one unit is defined as "The amount of enzyme that inhibited 50% of NBT photo reduction". Catalase (CAT) activity is determined with the help of (Liu et al., 2009) described method. For determination of 1.9 ml of phosphate buffer (pH 7), 1 ml of 5.9 Mm, and 0.1 ml of enzyme extract are included in the CAT activity reaction solution. Reaction solution approximately 200 µl is kept in 96 well plates and at 240 nm absorbance is taken after every 20 second. CAT activity one unit is defined as "0.01-unit changes in absorbance per minute. On the basis of proteins, each enzyme activity is expressed. Bradford is used to evaluate the protein concentration of crude extract. The Bradford (Bradford, 1976) method is used to quantify soluble protein. In this procedure, a micro centrifuge tube holds a 50l sample together with 2 ml of Bradford reagent. Whereas blank contained only Bradford reagent. At 595 nm frequency absorbance is taken. With the help of various concentration of BSA (brovine serum albumin) standard curve is prepared which used to determine the protein content.

RESULTS AND DISCUSSION

Growth parameters

It was observed that the S. cumini depicted significant variations regarding the plant height under salt stress as indicated in Figure 1A. The observed results showed that the plant height of S. cumini was maximum in T1 (control), and it gradually reduced with the increase the salt stress. The observed results showed that the stem diameter of S. cumini was maximum in T1 (control), and it gradually reduced with the increase the salt stress (Figure 1B). The observed results showed that the shoot fresh weight of S. cumini was maximum in T1 (control), and it gradually reduced with the increase the salt stress (Figure 1C). The observed results showed that the Root fresh weight of S. cumini was maximum in T1 (control), and it gradually reduced with the increase the salt stress (Figure 1D). The observed results showed that the root dry weight of S. cumini was maximum in T1 (control), and it gradually reduced with the increase the salt stress (Figure 1E). The observed results showed that the total biomass of S. cumini was maximum in T1 (control), and it gradually reduced with increasing the salt stress (Figure 1F).

Biochemical parameters

It was showed that the S. cumini regarding the CAT activity under salt stress as indicated in Figure 2A. The results showed that the CAT activity of S. cumini was maximum in T6 (20 dSm-1), and it gradually reduced with the increase the salt stress. The results showed that the POD activity of S. cumini was maximum in T6 (20 dSm-1), and it gradually reduced with the increase the salt stress (Figure 2B). The results showed that the SOD activity of S. cumini was maximum in T6 (20 dSm-1), and it gradually reduced with the increase the salt stress (Figure 2C). The observed results showed that the MDA of S. cumini was maximum in T6 (20 dSm-1), and it gradually reduced with the increase the salt stress (Figure 2D). The observed results showed that the total phenolic contents of S. cumini was maximum in T6 (20 dSm-1), and it gradually reduced with the increase the salt stress (Figure 2E).

Photosynthetic Parameters

It was showed that the Syzygium cumini depicted significant variations regarding the Chl a content under salt stress as indicated in Figure 3A. The observed results showed that the Chl a contents of S. cumini was maximum in T1 (control), and it gradually reduced with the increase the salt stress. The observed results showed that the Chl b contents of S. cumini was maximum in T1 (control), and it gradually reduced with the increase the salt stress (Figure 3B). The observed results showed that the total chlorophyll contents of S. cumini was maximum in T1 (control), and it gradually reduced with the increase the salt stress (Figure 3C). The observed results showed that the carotenoids S. cumini was maximum in T1 (control), and it gradually reduced with the increase the salt stress (Figure 3D). The observed results showed that the total soluble protein of Cumini was maximum in T1 (control), and it gradually reduced with the increase the salt stress (Figure 3E).

The salt stress caused a significant reduction in all the growth parameters. The reduction is greater under higher NaCl concentrations. The effect of different levels of salinity conditions on plant height, and plant growth (Roots and shoots length). plant dry matter production (roots and shoots dry weight). under salinity stress conditions are changed. The observed results depicted that the plant height of S. cumini was maximum in T1 (control), and it gradually reduced with the increase the salt stress. The plant height of S. Cumini at different stress levels ranged from 29.35 72.45 cm. The maximum plant height for S. cumini was 72.45 cm in T1 (Control) while the minimum plant height was 29.35 cm in T6 (20 dSm-1). The order of species response for the treatments was T1 (control) > T2 (4 dSm^{-1}) > T3 (8 dSm^{-1}) > T4 (12 dSm^{-1}) > T5 (16 dSm^{-1}) T6 (20 dSm^{-1}). The plant height of S. cumini at different stress level ranged from 2.445 -7.29 mm. The maximum stem diameter for S. cumini was 7.29mm in T1 (Control) while the minimum plant height was 2.445 mm in T6 (20 dSm-1). It was deficit that the S. cumini depicted significant variations regarding the shoot fresh weight under salt stress conditions. The observed results showed that the shoot fresh weight of S. cumini was maximum in T1 (control), and it gradually reduced with the increase the salt stress.

The total biomass of S. cumini at different stress levels ranged from 27.5-13.75 g. The maximum plant height for S. cumini was 27.5g in T1 (Control) while the minimum total biomass was 13.75 cm in T6 (20 dSm^{-1}). The order of species response for the treatments was T1 (control) > T2 (4 dSm^{-1}) > T3 (8 dSm^{-1}) > T4 (12 dSm^{-1}) > T5 (16 dSm^{-1}) T6 (20 dSm^{-1}). This study shows that salt stress as toxic ions, nutritional imbalance, and osmotic stress (Abbasi et al., 2016). have great negative impacts on the physiological and biochemical processes of

Syzygium cumini by impacting the rate of photosynthesis as well as protein synthesis which leads to lower production of growth hormones which cause the inhibition of plant growth.

Salinity stress significantly reduces plant growth for reasons including salinity osmotic influence, and ion-specific effects due to NaCl salt (Barkla et al., 2013; Gupta & Huang, 2014; Kumar & Sharma, 2020). As cell growth of plants is correlated with water in tissues salt stress causes the reduction in the water potential of plants it is a key factor for cell expansion and enhanced plant growth. Toxic ion impact because of NaCl salt on growth parameters because of abundance accumulation in the root system and plant cells. According to (Choudhury et al., 2013; Khalid et al., 2019; Seraglio et al., 2018) these toxic ions retard the water uptake by plants proceeded from enhanced soil solution osmotic pressure. Our findings suggested that as NaCl salinity levels increased growth of Syzygium cumini decreased. It was found that plant height significantly decreased with increasing salinity levels. It is due to salt stress accumulation in the cell walls, which modifies the metabolic pathway as well as decreases the shoot length. Moreover, cells appear sooner and cell walls become rigid (Aminullah et al., 2023; Singh et al., 2015).

The CAT activity in Syzygium cumini against salt stress it was depicted significant variations regarding the CAT activity under salt stress. The observed results showed that the CAT activity of S. cumini was maximum in T6 (20 dSm^{-1}), and it gradually reduced with the increase the salt stress. The CAT activity at different stress levels ranged from 29.35 -72.45-unit mg-1 protein. The maximum CAT activity for S. cumini was 5.693-unit mg-1 Protein in T6 (Control) while the minimum CAT activity was 1.692-unit mg^{-1} protein in T1 (control). POD activity in Syzygium cumini against salt stress condition. It was depicted significant variations regarding the POD activity under salt stress. The observed results showed that the POD activity of S. cumini was maximum in T6 (20 dSm^{-1}), and it gradually reduced with the increase the salt stress. The POD activity of S. cumini at different stress level ranged from 11.98 -37.61-unit mg^{-1} protein. The maximum POD activity for was 11.98 in T6 (Control) while the minimum POD activity was 37.61 in T1 (control). SOD activity against salt stress condition.

The observed results showed that the SOD activity of S. cumini was maximum in T6 (20 dSm^{-1}), and it gradually reduced with the increase the salt stress. The SOD activity of S. cumini at different stress levels ranged from 0.7876 -3.51-unit mg^{-1} protein. The maximum SOD activity for S. cumini was 3.51-unit mg-1 protein in T6 (Control) while the minimum SOD activity was 0.7876-unit mg^{-1} protein in T1 (control). MDA in Syzygium cumini against salt stress condition. It was shown that the S. cumini depicted significant variations regarding the MDA under salt stress. The observed results showed that the MDA of S. cumini was maximum in T6 (20 dSm^{-1}), and it gradually reduced with the increase the salt stress. The MDA of S. cumini at different stress level ranged from cm. The maximum MDA for Syzygium cumini was 5.08 $molg^{-1}fw$ in T6 (Control) while the minimum MDA contents were 1.68 in T1 (control). Phenolic activity in Syzygium cumini against salt stress condition. It was observed that the S. cumini depicted significant variations regarding the Phenolic activity under salt stress. The observed results showed that the Phenolic activity of S. cumini was maximum in T6 (20 dSm-1), and it gradually reduced with the increase the salt stress. The Phenolic activity of S. cumini at different stress level ranged from 1.68 to 5.08 mol g-1FW. The maximum Phenolic activity for S. cumini was 1.665 activity (mg/g-1) in T6 (Control) while the minimum MDA contents were 0.3595 in T1 (control).

Our study showed that salinity stress has significant effects on biochemical traits to limit the growth of plants. Salinity stress causes an excess amount of oxygen reactive species (ROS) by reducing the water potential. Such salinity stress generates oxygen-reactive species including superoxide radicals as well as hydrogen peroxide, which harm the cellular membrane, and macromolecules like proteins, lipids, DNA (Gull et al., 2019). To cope with oxidative constraints under salinity stress plants have a well-formed antioxidant defense system (Khan et al., 2021). As the main scavenger, SOD catalyzes the oxygen reactive species reaction which is problematic for chloroplasts, nucleic acids, and proteins (Gull et al., 2019), to produce hydrogen peroxide and Oxygen, and then POD catalyzes the hydrogen peroxide reaction to produce water and oxygen. SOD is amongst several prominent antioxidant enzymes capable of rehabilitation oxidative constraints caused by oxygen-reactive species (ROS). Therefore, SOD is considered a prominent enzyme in normal body regulation as well as in regulating intracellular oxygen reactive species (ROS) levels against oxidative damage. The present study resulted that SOD and POD values are enhanced with increasing salinity levels because of the endogenous defense system which triggers by plants to reduce damaging oxidative stress. Our experimental results found that antioxidant enzyme concentration under salinity stress enhanced as antioxidants are one of the fastest antioxidants against ROS to reduce oxidative stress. The present study is consistent with the results of (Aziz & Khan, 2001; Barkla et al., 2013; Choudhury et al., 2013) who worked on the impact of salinity on chickpeas (Bhattacharjee, 2014). The structural configuration of phenolic compounds having aromatic rings as well as free hydroxyl groups reveals the ideal chemistry to detoxify oxygen reactive species (ROS) (Khan et al., 2021; Seraglio et al., 2018; Shrivastava & Kumar, 2015). Photosynthetic pigments play a very important role in light absorption as well as energy transfer and are essential for photosynthesis. A reduction in chlorophyll value in leaves at high salinity is related to pigment destruction as well as instability of pigment-protein complexes along with chlorophyll activity. The Chl a in Syzygium cumini against salt stress condition. It was shown that the Syzygium cumini depicted significant variations regarding the Chl a under salt stress (Sarabi et al., 2019). The observed results showed that the Chl a of S. cumini was maximum in T1 (control), and it gradually reduced with the increase in the salt stress. The Chl a of S. cumini at different stress levels ranged from 0.2993 -0.7033 mg g^{-1} FW. The maximum Chl a S. cumini was 0.7033 mg g^{-1} FW in T1 (Control) while the minimum Chl a was 0.2993 mg g^{-1} FW in T6 (20 dSm^{-1}). The Chl b in Syzygium cumini against salt stress condition. The observed results showed that the total chlorophyll of S. cumini was maximum in T1 (control), and it gradually reduced with the increase the salt stress. The total chlorophyll at

different stress levels ranged from 0.8737 to -1.5007 mg g^{-1} FW. The maximum for S. cumini was 1.5007 mg g-1 FW in T1 (Control) while the minimum total chlorophyll was 0.8737 mg g-1 FW in T6 (20 dSm^{-1}). Carotenoids in Syzygium cumini against salt stress condition. It was observed that the Cumini depicted significant variations regarding the carotenoids under salt stress. The carotenoids of S. cumini at different stress levels ranged from 3.0307 -6.1851 mg g^{-1} FW. The maximum carotenoids for Cumini was 6.1851 mg g^{-1} FW in T1 (Control) while the minimum carotenoids were 3.0307 mg g^{-1} FW in T6 (20 dSm^{-1}). Photosynthetic pigments play a prominent role in light absorption as well as energy transfer and are essential for photosynthesis. A reduction in chlorophyll value in leaves at high salinity is related to pigment destruction as well as the instability of pigment-protein complexes (Assaha et al., 2017) along with chlorophyllase activity (Bordenave et al., 2014; Cha-Um & Kirdmanee, 2008). This enhanced the membrane permeability or loss of membrane integrity. Our results suggested that photosynthetic pigments are reduced because of salinity stress, which causes the accumulation of NaCl's toxic ions in chloroplasts. NaCl stress enhanced the synthesis of reactive oxygen radicals (ROS), as well as a reduction in chlorophyll contents due to oxidative constraint (Bordenave et al., 2014; Cha-Um & Kirdmanee, 2008; Gupta & Huang, 2014; Kumar & Sharma, 2020; Ullah et al., 2023).

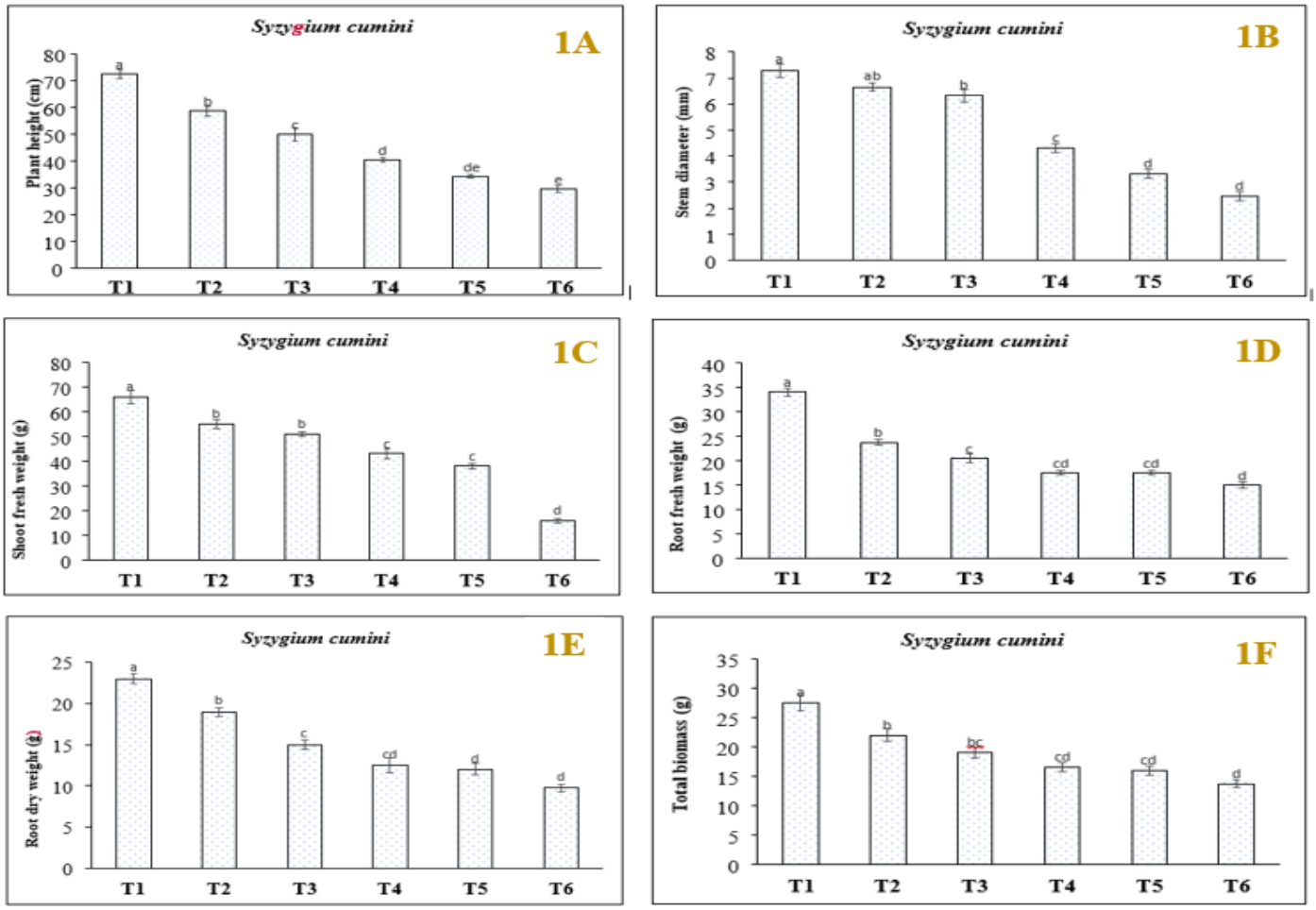

Figure 1: Significant variations regarding the growth parameters under salt stress conditions. In this figure 1A= plant height, 1B= stem diameter , 1C= shoot fresh weight, 1D= root fresh weight, 1E= root dry weight, 1F= total biomass,

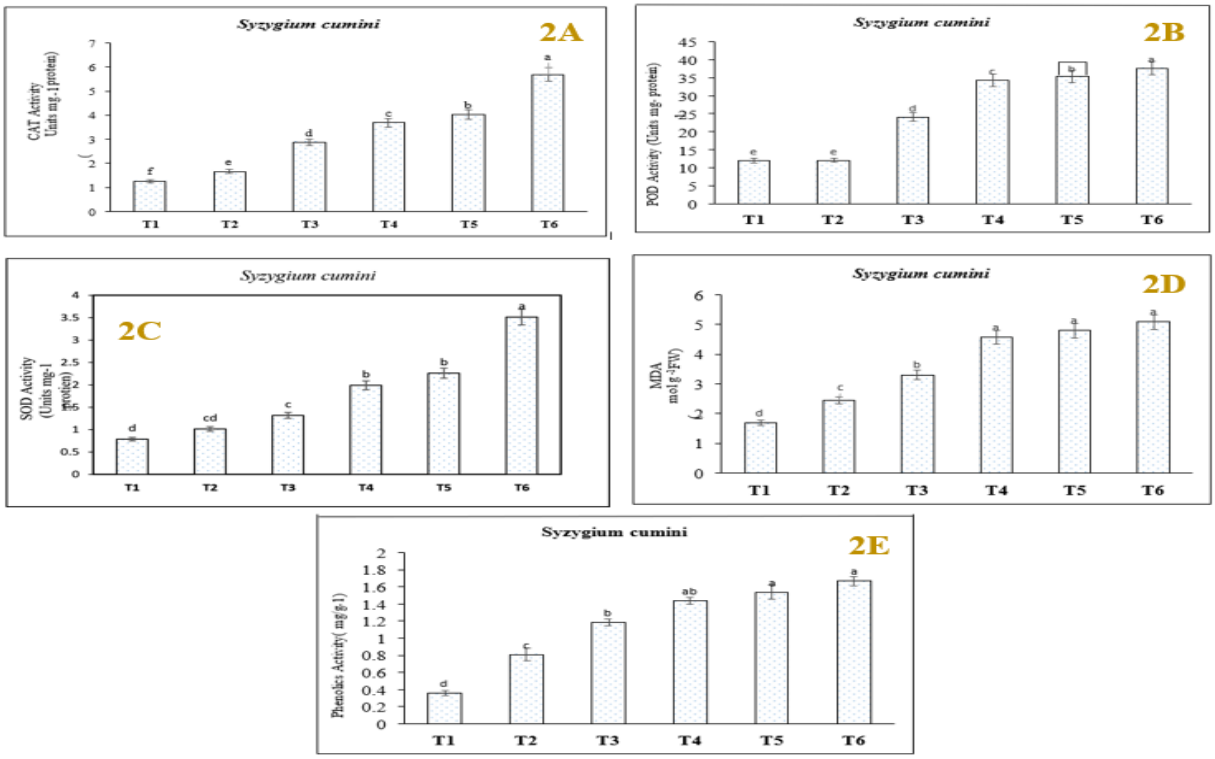

Figure 2: Significant variations regarding the Biochemical parameters under salt stress conditions. In this figure 2A= CAT activity, 2B= POD activity, 2C= SOD activity, 2D= MDA, 2E= total phenolic contents

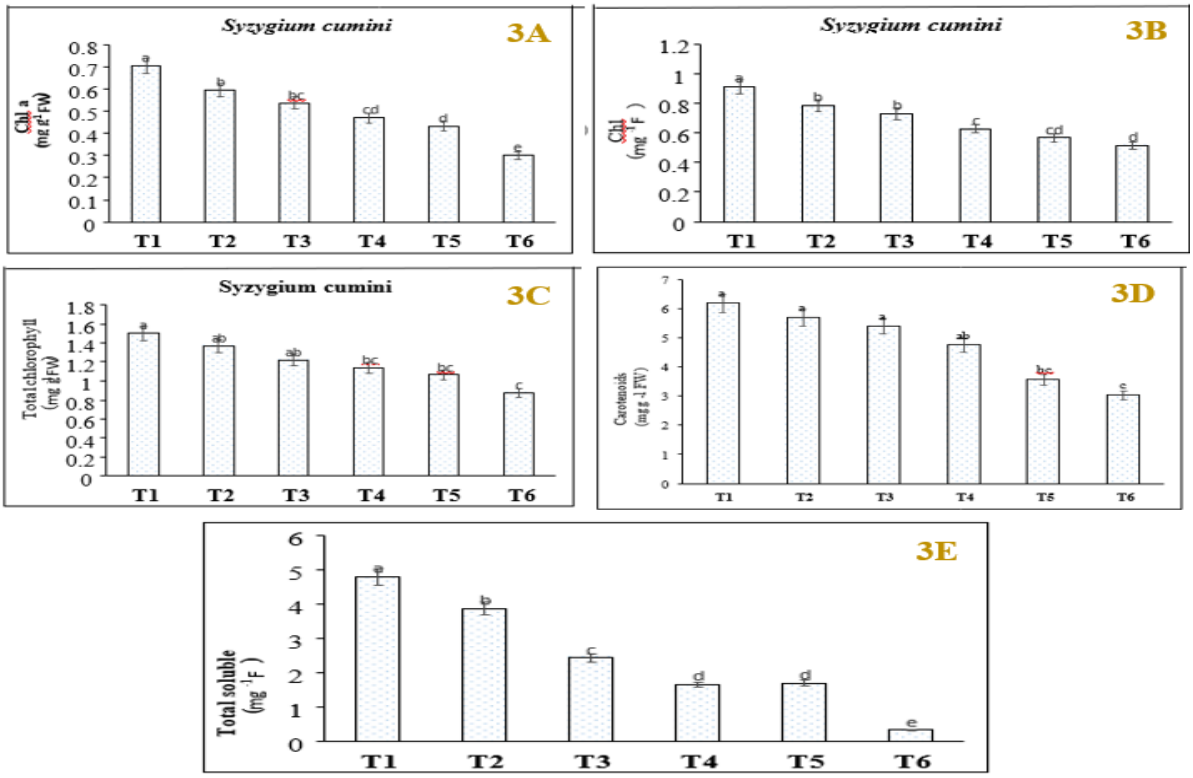

Figure 3: Significant variations regarding the Photosynthetic Parameters under salt stress conditions. In this figure 3A= Chl a content, 3B= Chl b contents, 3C= total chlorophyll contents, 3D= carotenoids, 3E= total soluble protein

CONCLUSION

This study demonstrated the significant impact of salt stress on the growth, biochemical, and photosynthetic parameters of Syzygium cumini seedlings. As salinity levels increased, a clear reduction in growth parameters such as plant height, stem diameter, shoot and root fresh weights, and total biomass was observed. Maximum growth occurred under control conditions (T1), while higher salinity treatments, particularly at 20 dSm^{-1} (T6), significantly inhibited growth. Biochemical responses also showed that antioxidant enzyme activities, such as CAT, POD, and SOD, increased under high salinity, indicating the plant's attempt to counteract oxidative stress. However, despite this response, photosynthetic pigments such as chlorophyll a, chlorophyll b, and carotenoids diminished, reflecting the negative influence of salinity on the plant's photosynthetic capacity. The results suggest that Syzygium cumini is moderately tolerant to salinity stress but exhibits significant physiological and biochemical adjustments to cope with elevated NaCl levels. Further studies could focus on enhancing salt tolerance mechanisms to optimize the growth of Syzygium cumini under saline conditions.

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