Biological and Clinical Sciences Research Journal
eISSN: 2708-2261; pISSN: 2958-4728
www.bcsrj.com
DOI: https://doi.org/10.54112/bcsrj.v2024i1.1216
*Biol. Clin. Sci. Res. J., Volume, **2024**: 1216*
Original Research Article

MORPHOLOGICAL AND PHYSIOLOGICAL RESPONSES OF DIFFERENT COTTON GENOTYPES UNDER NORMAL AND SALT STRESS CONDITIONS

RAFIQUE M[1], NISA ZU[2], MUNSHA A[3], BATOOL Z[3], *ASLAM I[1], FAHEEM J[4], NOFAL M[3], IMRAN M[5], ALI S[6], REHMAN A[7]

[1]*Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan*
[2]*Cotton Research Institute Multan, Pakistan*
[3]*Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan*
[4]*Department of Soil and Environmental Sciences, The University of Agriculture Peshawar, Pakistan*
[5]*Department of Agronomy, University of Agriculture, Faisalabad, Pakistan*
[6]*Soil and Water Testing Lab. Chiniot, Pakistan*
[7]*Chinese Academy of Agricultural Sciences. China*
***Corresponding author email address:** iqraaslam_91@gmail.com*

(Received, 2nd May 2024, Revised 8th September 2024, Published 9th September 2024)

Abstract *Salinity is a major abiotic stress that badly affects the growth and production of cotton worldwide. This scenario is not different in the case of Pakistan. This research was conducted to examine the effects of different salinity levels on the morpho-physiological characters of six cotton genotypes i.e. shoot and root length, fresh shoot and root weight, photosynthesis rate, and transpiration rate. A pot experiment was arranged with three salinity treatments of NaCl i.e. control (0 dS/m), T1 (4.5 dS/m), and T2 (8.5 dS/m) with three replications of each treatment. Highly significant decreases in shoot length, fresh shoot weight, fresh root weight, photosynthesis rate, and transpiration rate were observed with increasing salinity levels across all genotypes. The genotype MNH-786 showed the highest reduction in all morpho-physiological characters, indicating it was highly sensitive to salinity stress. On the other hand, FH-87 and FH-142 maintained relative performance for all discussed morpho-physiological traits under both moderate and high salinity, demonstrating that these are relatively more tolerant. These findings provided valuable insights into the salinity tolerance of cotton genotypes and highlighted the potential of FH-87 and FH-142 for cultivation in saline-prone areas and for use in breeding programs to improve salinity tolerance in cotton.*

Keywords: *cotton; Salinity; salt stress; seedling experiment*

Introduction

Salinity is a major abiotic stress that has decreased agricultural crop production worldwide, damaging more than 20% of irrigated lands and proving to be a serious threat to global food security. It is, also particularly hazardous for Cotton (Gossypium hirsutum L.) which is a major cash crop that contributes to the textile industry and the livelihoods of millions of farmers globally (Munns & Gilliham, 2015). Cotton is considered moderately tolerant to salinity, but its growth, yield, and fiber quality can still be badly affected by salinity (Razzaq et al., 2020). It exhibits osmotic and oxidative stress, ion toxicity, and nutrient imbalance, which collectively damage physiological characteristics such as photosynthesis, transpiration, and stomatal conductance (Ali et al., 2022).

Salinity affects the morphology and physiology of Cotton plants. The morphological traits, such as shoot length, fresh shoot weight, and fresh root weight are influenced by salinity due to disruption of cellular processes cell elongation, and division (Chen et al., 2021). In saline environments, Cotton plants often show stunted growth and reduction in biomass. This occurs due to the accumulation of toxic ions in tissues which disturbs water and nutrient uptake and reduces photosynthetic efficiency (Huang et al., 2022). Understanding the variability in salt tolerance of Cotton genotypes and studying the physiological and morphological responses is key to developing effective breeding strategies and management practices to cope with salinity stress (Farooq et al., 2017; Abbas et al., 2022; Raza, 2023; Rehman and Uzair 2023; Shahzad et al., 2022; Mushtaq et al., 2024).

The response of Cotton to salinity stress varies significantly in different genotypes, indicating the potential for selection and breeding salt-tolerant varieties. Some genotypes possess adaptations e.g.

[Citation: Rafique, M., Nisa, Z.U., Munsha, A., Batool, Z., Aslam, I., Faheem, J., Nofal, M., Imran, M., Ali, S., Rehman, A. (2024). Morphological and physiological responses of different Cotton genotypes under normal and salt stress conditions. *Biol. Clin. Sci. Res. J.*, **2024***: 1216*. doi: https://doi.org/10.54112/bcsrj.v2024i1.1216]

efficient stomatal regulation, osmotic adjustment, and ion homeostasis that allow them to maintain growth and physiology under saline conditions (Chen et al., 2021). For instance, genotypes that maintain higher transpiration rates and shoot growth under saline conditions often show better tolerance to salinity (Ali et al., 2022). However, the physiological mechanisms and adaptive characters are complex and involve multiple pathways, including hormonal regulation, reactive oxygen species (ROS) scavenging, and the activation of salt stress-responsive genes (Razzaq et al., 2020).

There is a need for identifying and characterizing salinity-tolerant Cotton genotypes. This study conducted a pot experiment to evaluate the effects of different salinity levels on the morphological and physiological characteristics of six cotton genotypes. Specifically, the study focused on assessing shoot length, fresh shoot weight, and fresh root weight under three salinity treatments to understand the variability in salinity tolerance. The data were analyzed using analysis of variance (ANOVA) to determine significant differences among genotypes and treatments. The findings from this study provide insights into the potential cotton genotypes for cultivation in saline-prone areas and contribute to the development of breeding programs targeting improved salinity tolerance in cotton.

Materials and Methods

Plant material

Table 1 Plant material evaluated for salinity tolerance and related institute of origin of genotypes

Genotype	Related Institutes
NIAB-78	Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan.
FH-87	Cotton Research Station (CRS), Faisalabad, Pakistan
FH-142	Cotton Research Station (CRS), Faisalabad, Pakistan
CIM-573	Central Cotton Research Institute (CCRI), Multan, Pakistan.
CIM-506	Central Cotton Research Institute (CCRI), Multan, Pakistan.
MNH-786	Cotton Research Station (CRS), Multan

The experiment was arranged in a controlled greenhouse environment under natural daylight with temperatures having range from 25°C (night) to 45°C (day). The relative humidity was maintained between 60-70%. The experiment was plotted in a Completely Randomized Design (CRD) with 3 salinity treatments control T1 and T2 and three replications for each variety.

The pots were used with dimensions of 30 cm in diameter and 40 cm in height, each filled with a soil mixture of loam, sand, and peat in a 1:1:2 ratio by volume. The soil mixture was sterilized by autoclaving at 121°C for 30 minutes to eliminate any pathogens. The electrical conductivity (EC) of the soil was initially measured and confirmed to be below 1 dS/m to ensure it was free from salinity.

Cotton seeds were sterilized with 2% sodium hypochlorite solution for 5 minutes, followed by thorough rinsing with distilled water. Five seeds of each variety were sown per pot at a depth of 2 cm. The seedlings were thinned to retain three uniform and healthy seedlings per pot after the completion of germination. The pots were watered with deionized water until the seedlings were well established (approximately 14 days after sowing). EC meter was used to prepare the irrigation water and the following doses were applied 2 times a week to maintain the salinity levels (Table 2). The experiment span was 40 days after the sowing. During the experimental period, the pots were rotated every week to minimize any positional effects in the greenhouse.

Table 2 Treatments applied to screening 6 cotton genotypes for salinity tolerance

Treatment	Description
Control	0 dS/m (Deionized water was applied)
T1	4.5 dS/m
T2	8.5 dS/m

Data recording

The data of the following characters were recorded by using standard methods and equipment.

Root Length (cm)

Plants were carefully uprooted, and root length was measured from the junction of root and shoot to the longest root tip.

Shoot length

Shoot length was measured from the base of the plant (where the shoot emerges from the soil) to the tip of the highest fully expanded leaf.

Fresh shoot weight

The seedling was cut from the junction of root and shoot. The fresh weight of each shoot was measured immediately after root length and shoot length in grams using an electronic balance with a precision of 0.01 g.

Fresh root weight

The fresh root weight was then measured using a weight balance with a precision of 0.01 g.

Stomatal conductance and photosynthesis rate

Measured on a clear sunny day between 12:00 and 2:00 pm using a portable infrared gas analyzer (IRGA) by putting leaves into the jaws of the device.

Results and discussions

Fig 1 shows the average shoot length in 6 cotton genotypes at different salinity treatments. It can be seen that shoot length is decreased with an increase in salinity level in all observed genotypes. This decrease is too much in the case of MNH-786. FH-

[Citation: Rafique, M., Nisa, Z.U., Munsha, A., Batool, Z., Aslam, I., Faheem, J., Nofal, M., Imran, M., Ali, S., Rehman, A. (2024). Morphological and physiological responses of different Cotton genotypes under normal and salt stress conditions. *Biol. Clin. Sci. Res. J.*, **2024***: 1216*. doi: https://doi.org/10.54112/bcsrj.v2024i1.1216]

87 and FH-142 have maximum shoot length in

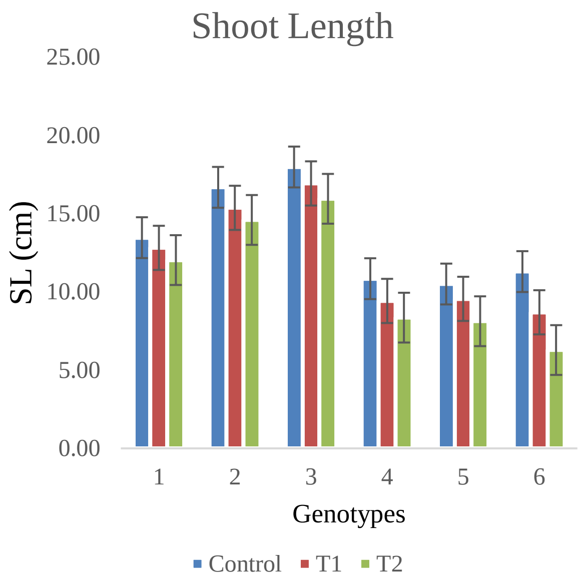

Fig 1 Mean performance of shoot length of 6 cotton genotypes under different salinity levels

Fig 2 shows the average performance of root length in 6 cotton genotypes at different salinity levels. It can be observed that root length is decreased with an increase in salinity level in all observed genotypes. This decrease is too much in the case of MNH-786. FH-87 and FH-142 have maximum shoot length in control, T1 and T2.

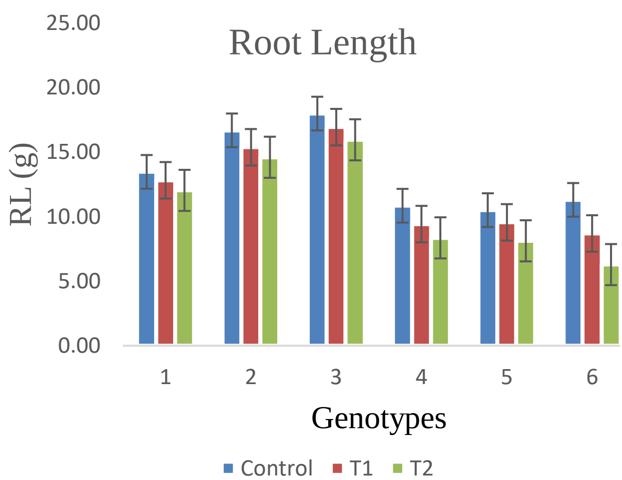

Fig 2 Mean performance of root length of 6 cotton genotypes under different salinity levels

Fig 3 shows the mean performance of fresh shoot weight in 6 cotton genotypes at different salinity levels. It can be observed that fresh shoot weight is decreased with an increase in salinity level in all observed genotypes. This decrease is too much in the case of MNH-786. FH-87 and FH-142 have maximum shoot length in control, T1 and T2.

control, T1 and T2.

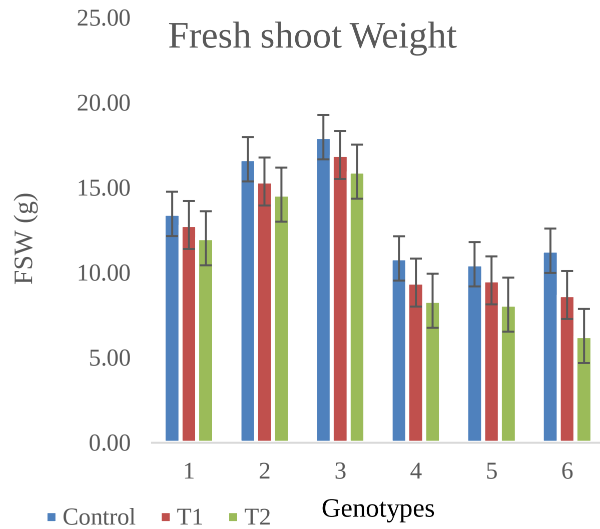

Fig 3 Mean performance of fresh shoot weight of 6 cotton genotypes under different salinity levels

Fig 4 shows the mean fresh root weight in 6 cotton genotypes at different salinity levels. It is demonstrated that fresh shoot weight is decreased with an increase in salinity level in all observed genotypes. This decrease is too much in the case of MNH-786. FH-87 and FH-142 have maximum shoot length in control, T1 and T2.

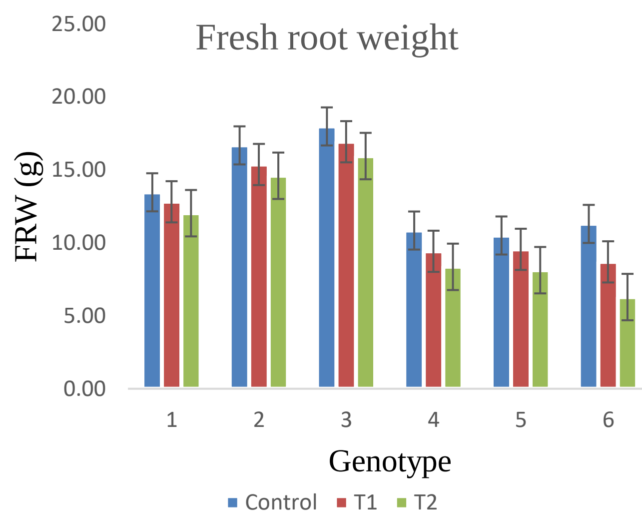

Fig 4 Mean performance of fresh root weight of 6 cotton genotypes under different salinity levels

Fig 5 shows the mean transpiration rate of 6 cotton genotypes at different salinity levels. The transpiration rate is found to be decreased with an increase in salinity level in all observed genotypes. This decrease is too much in the case of MNH-786. FH-87 and FH-142 have maximum shoot length in control, T1 and T2.

[Citation: Rafique, M., Nisa, Z.U., Munsha, A., Batool, Z., Aslam, I., Faheem, J., Nofal, M., Imran, M., Ali, S., Rehman, A. (2024). Morphological and physiological responses of different Cotton genotypes under normal and salt stress conditions. *Biol. Clin. Sci. Res. J.*, **2024**: *1216*. doi: https://doi.org/10.54112/bcsrj.v2024i1.1216]

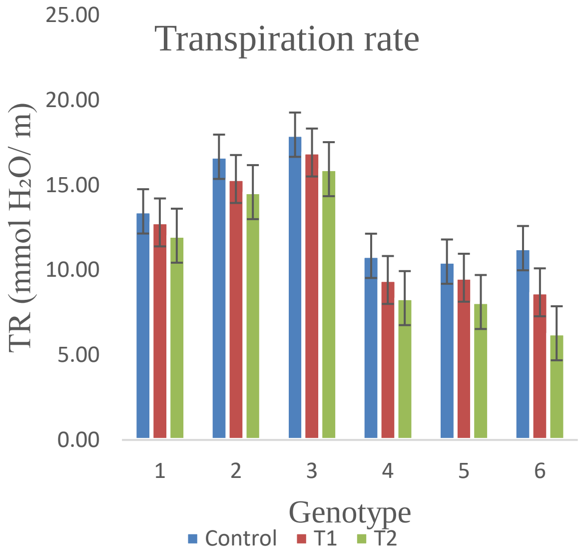

Fig 5 Average transpiration rate of 6 cotton genotypes under different salinity levels

Fig 6 shows the average photosynthesis rate of 6 cotton genotypes at different salinity levels. The photosynthesis rate is found to be decreased with an increase in salinity level in all observed genotypes. This decrease is too much in the case of MNH-786. FH-87 and FH-142 have maximum shoot length in control, T1 and T2

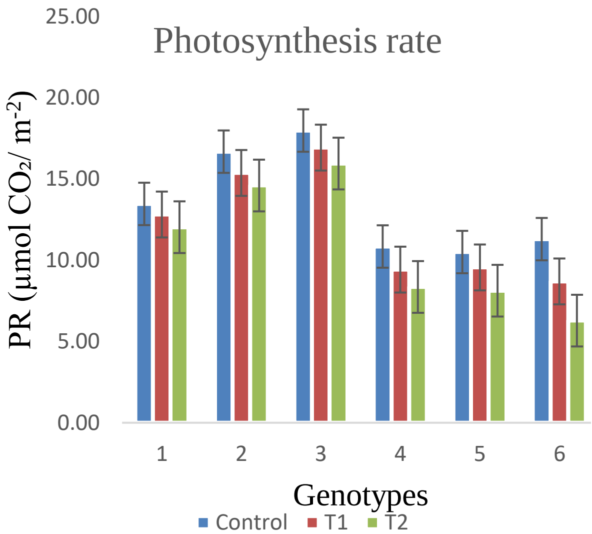

Fig 6 Mean photosynthesis rate of 6 cotton genotypes under different salinity levels

In table 3 the MSS values of genotypes and treatments obtained from analysis of variance are represented. MSS of genotypes of all the characters was highly significant. The performance of genotypes was found very different from each other. The performance of genotypes in all characters was also highly significant means that all treatments of salinity had different effects on plant growth

Table 3 MSS values of genotypes and treatment for morpho-physiological characters of cotton

Character	MSS Genotypes	MSS Treatments
Fresh root weight	88.08**	96.95**
Fresh shoot weight	88.63**	98.01**
Root length	139.71**	27.97**
Shoot length	122.74**	33.32**
Photosynthesis rate	122.69**	33.31**
Transpiration rate	122.94**	33.37**

Shahid et al. (2011) reported that MNH-786 showed significant yield reduction under saline conditions. This occurred due to a disturbed transpiration rate. In this study, decrement in shoot length was noted that supports the susceptibility of MNH-786 and its limited potential for cultivation in saline areas. FH-142 was reported as a salt-tolerant genotype having better growth and physiological performance under saline conditions (Ashraf & Ahmad, 2000). FH-87 and FH-142 had higher shoot lengths. High transpiration rate and photosynthesis rate were the reported reasons for the ability of FH-87 and FH-142 to maintain relatively higher shoot lengths under salinity stress (Tavakkoli et al., 2011). MNH-786 exhibited the most significant reduction in transpiration rate under both moderate (50 mM NaCl) and high salinity levels (100 mM NaCl) (Shahid et al., 2021). This finding was similar to the present study where MNH-786 has been identified as a salt-sensitive genotype. On the other hand, FH-87 and **FH-142** showed relatively higher transpiration rates at all salinity levels (control, T1, and T2) compared to the other genotypes, indicating a high salt tolerance (Shahid et al., 2021). The ability of these genotypes to maintain a relatively high transpiration rate under stress conditions suggested that they possess adaptive mechanisms such as efficient stomatal regulation, osmotic adjustment, and high photosynthesis rate, which help endure the adverse effects of salinity (Chen et al., 2021). This finding is consistent with present studies that reported FH-142 as a salt-tolerant genotype having better growth and physiological functions under salt stress.

Conclusion

Salinity stress reduced the shoot and root length, fresh shoot weight, and fresh root weight in observed cotton genotypes, with highly significant variation in tolerance among them. Genotypes FH-87 and FH-142 showed relative tolerance by maintaining higher growth and biomass under saline conditions which make them fit for cultivation in saline-prone areas. These findings may be useful in future breeding programs aimed at enhancing salinity tolerance in cotton.

References

[Citation: Rafique, M., Nisa, Z.U., Munsha, A., Batool, Z., Aslam, I., Faheem, J., Nofal, M., Imran, M., Ali, S., Rehman, A. (2024). Morphological and physiological responses of different Cotton genotypes under normal and salt stress conditions. *Biol. Clin. Sci. Res. J.*, **2024***: 1216*. doi: https://doi.org/10.54112/bcsrj.v2024i1.1216]

Abbas, A., Rehman, A. U., Bukhari, M. S., & Abbas, M. Z. (2022). Exploring the genetic resources of cotton. *Journal of Life and Social Sciences*, ***2022***(1), 1-1.

Ali, Q., Ali, A., Hussain, M., Ali, M., & Abbas, A. (2022). Insights into cotton salt tolerance: Physiological and molecular perspectives. *Plants*, 11(2), 193.

Ashraf, M. (2010). Inducing salinity tolerance in plants: Some recent advances. *Critical Reviews in Plant Sciences*, **29**(4), 230-243.

Ashraf, M., & Ahmad, S. (2000). Influence of sodium chloride on ion accumulation, yield components and fiber characteristics in salt-tolerant and salt-sensitive lines of cotton (Gossypium hirsutum L.). *Field Crops Research*, **66**(2), 115-127.

Chen, D., Wang, S., Cao, B., & Yang, H. (2021). Regulation of water and ion homeostasis in plants under salt stress. *Plants*, **10**(3), 560.

Chen, D., Wang, S., Cao, B., & Yang, H. (2021). Regulation of water and ion homeostasis in plants under salt stress. *Plants*, **10**(3), 560.

Farooq, M., Hussain, M., Wakeel, A., & Siddique, K. H. M. (2017). Salt stress in maize: Effects, resistance mechanisms, and management. *Agronomy for Sustainable Development*, **37**(4), 48.

Huang, X., Guo, C., Zheng, Y., & Lou, C. (2022). Advances in understanding plant tolerance to salt stress: Molecular mechanisms and breeding strategies. *Plant Physiology and Biochemistry*, **169**, 39-48.

Munns, R., & Gilliham, M. (2015). Salinity tolerance of crops: What is the cost? *New Phytologist*, **208**(3), 668-673.

Mushtaq, F., Akram, M. H., Usman, M., Mohsin, M., & Nawaz, M. S. (2024). Global climate change and its influence on crop production. *Journal of Life and Social Sciences*, **2024**(1), 27-27.

Raza, A. (2023). Breeding crop plants using molecular genetics, genomics, and biotechnology. *Journal of Life and Social Sciences*, **2023**(1), 19-19.

Razzaq, M., Hafeez, M. B., Shaheen, M. R., Ansar, M., Akram, H. M., & Wang, X. (2020). Salinity stress in cotton: Effects, mechanisms of tolerance, and its management strategies. *Physiology and Molecular Biology of Plants*, **26**(5), 837-859.

Rehman, A. U., & Uzair, M. (2023). Genetic variation and association of various chickpea (Cicer arietinum L.) traits at seedling stage. *Journal of Life and Social Sciences*, **2023**(1), 17-17.

Shahid, M. A., Balal, R. M., Pervez, M. A., Abbas, T., Aqeel, M., Garcia-Sanchez, F., & Mattson, N. S. (2021). Effect of salinity on physiological characteristics, nutrient status, and biochemical constituents of okra (Abelmoschus esculentus L.). *Horticulture, Environment, and Biotechnology*, **62**(4), 573-585.

Shahid, M. A., Pervez, M. A., Balal, R. M., Ahmad, R., Ayyub, C. M., Abbas, T., & Akhtar, G. (2011). Salt stress effects on some morphological and physiological characteristics of okra (Abelmoschus esculentus L.). *Soil and Environment*, **30**(1), 66-73.

Shahzad, A., Hamid, A., Hussain, A., Rashid, M., Khan, M., & Hussain, Z. (2022). Current situation and future prospects of wheat production in Pakistan. *Journal of Life and Social Sciences*, **2022**(1), 5-5.

Tavakkoli, E., Fatehi, F., Coventry, S., Rengasamy, P., & McDonald, G. K. (2011). Additive effects of Na+ and Cl− ions on barley growth under salinity stress. *Journal of Experimental Botany*, **62**(6), 2189-2203.

Declaration

Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

The study was approved by authors.

Funding Statement

Not applicable

Authors' Contribution

All authors contributed equally.

Conflict of interest

There is no conflict of interest among the authors of the manuscript.

[Citation: Rafique, M., Nisa, Z.U., Munsha, A., Batool, Z., Aslam, I., Faheem, J., Nofal, M., Imran, M., Ali, S., Rehman, A. (2024). Morphological and physiological responses of different Cotton genotypes under normal and salt stress conditions. *Biol. Clin. Sci. Res. J.*, **2024***: 1216*. doi: https://doi.org/10.54112/bcsrj.v2024i1.1216]