Effect of salt stress on anatomical features in Plants

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ABSTRACT

Salinity is known to influence several features of the metabolism in plants and to stimulate modifications in their anatomy as well as morphology. These modifications are often regarded as adaptations which enhances the probabilities of the plant to tolerate the stress caused by salinity; on the other hand, they might be regarded as indication of damage as well as disturbances in the normal balance of life processes. The anatomical as well as morphological characteristics distinctive of halophytes are generally regarded as be adaptations for salinity. Extra proves are available for glycophytes and particularly cultivated crops, permitting comparison between the similar attributes in saline as well as non-saline environment. But whether these alterations are because of the salt stress in these plants should be regarded as adaptations or as indications of damage, is open for discussion.

Key Words: Salt stress, Cell diameter, Cell layers, Root anatomy, shoot anatomy, leaf anatomy

INTRODUCTION

Salt stress is a highly significant abiotic stress which influences plant growth as well as development worldwide (Al-Maskri et al., 2010; Muchate et al., 2016). Salinity influences plant metabolic irregularities through, ion toxicity, osmotic stress, nutrient imbalance as well as oxidative stress causing cellular impairment and ultimately plant death (Hasegawa, 2000; Zhu, 2001; Farooq et al., 2015; Slama et al., 2015). The potential of the plant to resist salt stress is a complicated property having several physiological as well as biochemical processes, particularly regulating the production of reactive oxygen species (Gong et al., 2013) with photosynthesis (Stefanov et al., 2016, Chen et al., 2019).

Salinity is regarded as highly significant problems in agricultural history (Srivastava and Sharma, 2019). It restricts agricultural production especially through damaging the crop yields (Abernethy et al., 1998). Globally, it was found that almost 1125 million hactare agricultural lands tolerating salt stress, of which 76 million hactare of cultivated area are under the influence of man-made salinity as well as sodicity (Aguirre-Medina et al., 2002). Approximately one-fifth of cultivated area is influenced through salt stress and each year 1.5 million hactare cultivated area lost for crop production. As it continues, half of the agricultural area will be lost till 2050 (Riederer and Schreiber, 2001, Bleeker et al., 2012). Salt stress is caused by high amount of soluble salts and at the ECe value of 4 dS per meter or higher, the soil is regarded as saline. Salinity forms stress in two modes (Aguirre-Medina et al., 2002). The salts at greater level in the soil makes it difficult to get water inside the cells of roots and causes toxicity in plants. The salt exterior to plant root influences expansion as well as growth of the cell directly. Harmful level of salt need time for storage before influencing the plant (Aguirre-Medina et al., 2002). The impacts of salinity such as growth and expansion of cell, plant membrane abnormality, modifications in metabolic process, the mode of germination, photosynthetic activity, ion toxicity, lengths of shoot and root, leaf development are undisputable (Hasegawa et al., 2000, Munns, 2002) and plants adapts certain process to remove these harmful influences. Since Sodium Chloride is the most soluble as well as common salt, every plant develop processes for controlling the storage of Sodium Chloride (Munns, 2005). Halophytic, plant species which develop under high salinity have improved maintenance in comparison to glycophytes, that do not possess any resistance to high salt stress (Garthwaite et al., 2005). As the salt stress is usual in arid as well as semiarid areas, tolerance processes of plants exist as per these leslows water potential regions (Munns and Tester, 2008). To tolerate these toxic influences of salt stress, plants induce several different physiological, morphological, as well as biochemical adaptations (Motos et al., 2017, Yildiz et al, 2020).

Generally, glycophytic crop species initiate a growth reduction response on exposure to salt. This can be attributed to fact that glycophytic species fail to distinguish desiccation environments from salt environments (Singh et al., 1989). The reduced growth rate in the saline environment not only results in drastic decrease in the crop yield but may even endanger the survival of the plant. Salt tolerant or halophytic plants can minimize the detrimental effects of salts by modifying morphological, anatomical and physiological mechanisms of salt tolerance (Hameed et al., 2009).

Effect of salt stress on growth

High salt concentration influences every stages of plant growth as well as development, enabling the plants to tolerate a complicated regulatory network for survival in stressed environment. The harmful influences of stress over morphology, anatomy, growth, ultra-structure with metabolism were observed by different investigators in various plant species (Shao et al., 2008, Riaz et al., 2013). Amongst several abiotic stresses, Sodium Chloride generated salt stress is the prime cause that disturbs the plant growth as well as development, reduces germination and eventually reduces establishment of plant and production. Decrease in growth, production as well as quality in saline environment happens because of reduction in the capacity of plants to derive water from the soil solution as well as disturbs the structure of soil. Saline soil could result in alterations in plant metabolism, resulting in reduced growth, decreasing activities of enzymes and biochemical ingredients (Muthukumarasamy and Panneerselvam, 1997). Salinity causes anatomical changes in the body of plants and make them able to minimize the harmful influences of salinity. The impact of salt stress over anatomical structure was described by Gadalla (2009) and Younis et al. (2014). The harmful impact of salt stress on growth was also observed by Hussein et al. (2009), Abdel-Monem et al. (2010), Saffan (2008) and Younis et al. (2014). It is, therefore important to understand the mechanism of physiological adaptation as well as changes in anatomical structure under salinity that may help plant breeder to evolve a salt tolerant variety.

Effect of Salinity on cell anatomy

Actually, plants respond to salt stress in many ways including reduced cell expansion (Binzel et al., 1989, Greenway and Munns, 1980,). Primary influence of salinity in plants is the decrease in rate of growth. Growth of plant could be influenced through salt stress in several ways. Initially, capacity of the water intake inside the plant is decreased in the presence of soil salinity which results in very rapid decrease in the of growth rate. The osmotic influences of the soil solution which have salt results in primary stage of the growth response and generates a set of influences just like water stress (Munns 2002). The time period for which a plant is treated with salt chooses the process through which salt stress influences plant growth. Munns (2002) described the stepwise stages of the plant cultivated under salt stress. As water is removed from cells in the initial few seconds or minutes, it causes it to shrink. The cells attain their original shape after some hours however, the extension rate is yet decreased. This results in less growth rates of leaf as well as root. Rates of cell division are also influenced for days and further participate in lowering the rates of leaf as well as root growth. The reduction in cortical cell size in roots under salt stress might be due to low water availability. It is suggested that cell expansion may have been metabolically limited by the accumulated sodium. According to Flowers and Yeo (1989), salt-tolerance would be expected to involve mechanism which limits the accumulation of these ions in leaves. Given that there is a maximum acceptable limit on cellular ion concentration, an increase in delivery accommodated by an increase in size or an increase in cell number (a branched habit).

It is evident that increase in salt in soil has opposite influence on xylem as well as phloem region of the shoot and root because their area inclined to reduce in saline environment. It was because of the decrease in water intake in the plants at higher salt concentration and this causes osmotic environment in the cell. Salt stress influences plant growth by osmotic influences as well as ion toxicity (Hampson and Simpson, 1990). Salinity results in decrease of cell turgor and decreases root and stem elongation rate in ornamental plants (Fricke et al., 2006; Younis et al., 2014b) which decreases area of shoot and root. Under salt stress less xylem and phloem region of shoot and roots was observed by Datta and Som (1973) and Reinoso et al. (2004) in *Prosopis strombulifera*. These studies are same with Nadia (1998), Soha (2006) and Baum et al. (2000) as the xylem region of stem reduced because of dexrease in width and length of xylem. Salt stress decreased both its phloem and sieve region at higher concentration, and these results are also interrelated with less resistant species (Goncharova and Dobrenkova， 1981). Salt stress resulted in the gradual modifications in internal structure of plant that decreases the xylem as well as the phloem region (Hameed et al., 2010). Xylem vessels also decreased in salinity, as observed by LingAn et al. (2002). These researches are just opposite to the conclusions of Akram et al. (2002) and Hu et al. (2005) who observed less meta xylem as well as cortical arregionea, but there was no certain response in the cortical thickness and its cell area in the stem. Cortex region of root as well as stem was also considerably reduced at high concentration of salt. Microscopic investigations exhibited visible cell damages at 100 mg per liter of Sodium Chloride in stem whereas the root cells damages were seen at 50, 75 and 100 mg per liter of Sodium Chloride. The cortex cells of root were damaged as these regulate the salt transport inside the root. In cortex cells of stem, 50 and 75 mg per liter of Sodium Chloride displayed no harm as the root cortex assists in decreasing the transport into the stem. These cell damages decreased the growth as well as cortex tissue area in roots and stem. These studies are supported by findings of Casenave et al. (1999), in which they have shown reduced cortex in cotton seedlings at greater salt concentration. Walsh (1990) proposed that the width of cortical region grows upto a certain extent, however in critical environment it reduces. Therefore, cortical cell area reduced at higher salinity levels, as observed by Akram et al. (2002), but enhanced cortical region under salinity in salt resistant species might be crucial in physiological drought for its improved accumulation potential (Baloch et al., 1998). As salt concentration rises, root diameter in *Gazania* reduced, as observed by De Villiers et al. (1995). In 1999, a botanist, Degano, (1999) corelated root succulence with the process of acclimatization to saline environment. Wider meta phloem region of root was attained in high salt concentration which showed its improved tolerance to higher salt stress (Awasthi and Pathak, 1999). The less influenced root region in the salinity resistant species might be for their improved acclimatization. These results of cortex are similar to the studies of Akram et al. (2002) who observed that cortical region of root reduced with enhancement of salt concentration (Younis et al. 2014)

CONCLUSION:

Plants resistant to salt, utilize various adjustments to adapt to salinity stress, like physiological, biochemical, and morphological alterations. Additionally, plants also adapt to salt environment through modifying their roots, leaves, anatomical as well as morphological changes. The leaf as well as roots are amongst the vital plant organs which are involved in the movement of water with minerals utilized for photosynthesis. From a plant physiology point of view, level of water utilization efficiency of carbon dioxide fixed in photosynthesis in comparison to the leaf anatomy. There is less research has been done on the ultrastructure modifications induced under salinity stress.

REFERENCES

1. Abdel-Monem, A.A., H.M.S. El-Bassiouny, M.M. Rady and M.S. Gaballah. 2010. The role of tryptophan and prozac (S-hydroxy tryptophan) on the growth, some biochemical aspects and yield of two sunflower cultivars grown in saline soil. International Journal of Academic Research. 2: 225-231
2. Abernethy GA, Fountain DW, McManus MT. Observations on the leaf anatomy of Festuca novae-zelandiae and biochemical responses to a water deficit. New Zealand Journal of Botany. 1998;36(1):113-123
3. Aguirre-Medina JF, Gallegos JAA, del Ruiz Posadas L, Shibata JK, Lopez CT. Morphological differences on the leaf epidermis of common bean and their relationship to drought tolerance. Agricultura technical en mexico. 2002;28(1):53-64

4. Al-Maskri, A., L. Al-Kharusi and H. Al-Miqbali, 2010. Effects of salinity stress on growth of lettuce (Lactuca sativa) under closed-recycle nutrient film technique. Intl. J. Agric. Biol., 12: 377–380
5. Antunes WC, Provart NJ, Williams TCR, Loureiro ME. Changes in stomatal function and water use efficiency in potato plants with altered sucrolytic activity. Plant, Cell and Environment. 2012;35(4):747-759. DOI: 10.1111/j.1365-3040.2011.02448.x
6. Binzel, M.L., Hasegawa, P.M., Handa, A.K. and Bressan, R.A. 1989. Adaptation of tobacco cells to NaCl. Plant Physiol., 79, 118-125.
7. Bleeker PM, Mirabella R, Diergaarde PJ, VanDoorn A, Tissier A, Kant MR, et al. Improved herbivore resistance in cultivated tomato with the sesquiterpene biosynthetic pathway from a wild relative. Proceedings of the National Academy of Sciences of the United States of America. 2012;109(49):20124-20129. DOI: 10.1073/pnas.1208756109
8. Bresler, E., McNeal, B.L. and Carter, D.L. 1982. Saline and sodic soils. Principles-Dynamics-Modelling, Advanced Series in Agricultural Sciences, 10, Springer-Verlag, Berlin.
9. Chen, T., R. Zeng, X. Wang, J. Zhang, D. Ci, Y. Chen, X. Wang, S. Wan and L. Zhang, 2019. Growth and physiological responses of peanut seedling to salt stress. Intl. J. Agric. Biol., 22: 1181–1186
10. Farooq, M., M. Hussain, A. Wakeel and K.H.M. Siddique, 2015. Salt stress in maize: effects, resistance mechanisms, and management. A review. Agron. Sustain. Dev., 35: 461–481
11. Flowers, T.J. and Yeo, A.R. 1989. Effect of salinity on plant growth and crop yields. Environmental Stress in plants. NATO ASI Series, G19, Ed. J.H. Cherry. Springer-Verlag, Berlin, 101-119.
12. Franks PJ, Doheny-Adams WT, Britton-Harper ZJ, Gray JE. Increasing water-use efficiency directly through genetic manipulation of stomatal density. New Phytologist. 2015;207(1):188-195. DOI: 10.1111/nph.13347
13. Gadallah, M. 1999. Effects of proline and glycinebetaine on Vicia faba responses to salt stress. Biol. Plant., 42(2): 249-257.
14. Galmés J, Ochogavía JM, Gago J, Roldán EJ, Cifre J, Conesa MÀ. Leaf responses to drought stress in mediterranean accessions of solanum lycopersicum: Anatomical adaptations in relation to gas exchange parameters. Plant, Cell and Environment. 2013;36(5):920- 935. DOI: 10.1111/pce.12022
15. Garbarino, J. and Dupont, F.M. 1988. NaCl induces a Na^+/H^+ antiport in tonoplast vesicles from barley roots. Plant Physiol., 86, 0231-0236.
16. Garthwaite AJ, Colmer TD, Bothmer RV. Salt tolerance in Wild Hordeum species is associated with restricted entry of Na+ and Cl− into the shoots. Journal of Experimental Botany.2005;56(419):2365-2378. DOI: 10.1093/jxb/eri229
17. Gersani, M., Graham, E.A and Nobel., P.S. 1993. Growth responses of individual roots of Opuntia ficus-indica to salinity. Plant Cell Environ., 827-834.
18. Gong, B., D. Wen, K. Vandenlangenberg, M. Wei, F. Yang, Q. Shi and X. Wang, 2013. Comparative effects of NaCl and NaHCO3 stress on photosynthetic parameters, nutrient metabolism, and the antioxidant system in tomato leaves. Sci. Hortic., 157: 1–12
19. Greenway, H. and Munns, R. 1980. Mechanism of salt tolerance in non-halophytes. Ann. Rev. Plant Physiol., 31, 149-190.
20. Hajibagheri, M.A., Yeo, A.R., Flowers, T.J. and Collins, J.C. 1989. Salinity resistance in Zea mays: Fluxes of potassium, sodium and chloride, cytoplasmic concentrations and microsomal membrane lipids. Plant Cell Environ., 12, 753-757.