Impact of Seawater Salinity on Morpho-Biochemical, Photosynthesis, Ultrastructure of Chloroplasts and Oleosomes in Relation to Fat Metabolism in Flag Leaf of Two Wheat Cultivars During Grain-Filling

Heshmat Aldesuquy*

Department of Botany, Mansoura University, Egypt

Submission: March 01, 2017; Published: April 03, 2017

*Corresponding author: Heshmat Aldesuquy, Department of Botany, Faculty of Science, Mansoura University, Mansoura, Egypt, Email: heshmat-aldesuquy@hotmail.com

Abstract

To cope with the scarcity of fresh water for the sustainable development of agriculture, there is increasing awareness among agricultural scientists and planners in the utilization of seawater (at least diluted) for irrigation of crops. Different responses of two wheat (Triticum aestivum L.) cultivars (Gemmieza-9 and Sids-1) subjected to seawater at a percentage of 10% or 25% were investigated. Gemmieza-9 would be classified as a species susceptible to seawater salinity, because its growth and physiological parameters, such as dry and fresh weight at the whole plant level, leaf area, specific leaf area, shoot to root ratio on the basis of length, some water relations (i.e. relative water content, saturation water deficit, degree of leaf succulence and degree of leaf sclerophylly) and leaf protein and nucleic acids (DNA and RNA) contents were severely affected by seawater stress in comparison to Sids-1. Genotype Sids-1 appears to be more tolerant to seawater salinity than Gemmieza-9 since it is able to maintain less amounts of Na+ and Cl- and higher amounts of organic solutes (TSS, TSN, proline, organic acids, glycerol and inorganic ions (K+, Ca2+, Mg2+ and K+/Na+ ratio) in its flag leaf. In addition, this review provides scarce evidence supporting the hypothesis that osmotic adjustment (OA) plays a preponderant role in the resistance to seawater stress in both wheat cultivars. It was clear that osmotic adjustment degree affected by the rate of stress intensity. Furthermore, osmotic adjustment OA could be a part of the salt tolerance mechanisms developed by wheat and could be exploited in breeding programs for improved salt stress tolerance. A noticeable decline in chloroplast numbers in flag leaves of both wheat cultivars treated with sea water. This reduction could be attributed to the fact that salt stress often induces premature senescence. Furthermore, the observed decrease in the oleosome volume and fatty acids un saturation level together with the increase in lipase activity and glycerol content in the flag leaves is correlated well with the wheat plant tolerance to seawater salinity. Seawater-stress reduced bio-membrane stability through inducing lipid peroxidation resulting in an increase in membrane leakage. Considering all our results antioxidative response is well correlated with growth sensitivity and tolerance of cultivars to seawater-salinity and we can conclude that Sids-1 that could induce more efficiently antioxidative enzyme system is more tolerant towards seawater irrigation than the cultivar Gemmieza-9. The present review suggests that markers for oxidative stress, particularly malondialdehyde content, membrane leakage, and membrane stability index as well as antioxidant enzyme activities can be used as simple, rapid and cost-effective, as potential indicators for in wheat genotypes.

Keywords: Growth vigor; Osmotic adjustment; oxidative damage; Oleosomes, Photosynthesis; wheat; Sea water

Abbreviations: MDA: Malondialdehyde; ML: Membrane Leakage; MSI: Membrane Stability Index; MUFA: Mono-Unsaturated Fatty Acids; PUFA: Poly-Unsaturated Fattyacids; SW: Sea Water; TSFA: Total Saturated Fatty Acids

Introduction

A biotic pressures like salt stress can impose limitations on crop productivity and also limit land available for farming, often in regions that can ill afford such constraints, thus highlighting a greater need for understanding how plants respond to adverse conditions with the hope of improving tolerance of plants to environmental stress [1]. Water is imperative for plant growth and development. The scarcity of fresh water and soil salinity are the two most important abiotic stresses facing today’s agriculture [2].

The controlled use of alternative water resources like brackish or seawater could be a valid tool to face drought in the Mediterranean regions. The efficient application of seawater depends on the convenient dilution and use of suitable plant genotypes and
Lipid peroxidation rate was found to increase with increase of salt stress especially in sensitive cultivars [18]. In connection, Joshi et al. [19] stated that with increasing level of salinity stress, the malondialdehyde (MDA) content increased in four Brassica juncea varieties. Nichols et al. [20] found that in Shewanellagelidimarina, under hyper-osmotic and hypo-osmotic stress conditions, an increase in the proportion of saturated fatty acids was accompanied with increasing salinity level. Moreover, Xu and Beardall [21] revealed that in a green microalga, the proportion of total, saturated and mono unsaturated fatty acids increased, while total polyunsaturated fatty acids decreased. In this connection, Ivanova et al. [22] cleared that plant leaves improve their resistance to salt stress by decreasing the lipid membrane permeability through increasing the amount of saturated fatty acids. The shortage of fresh water is compelling researchers to investigate the use of saline water for irrigation [23]. Thus, the present review was put forward to add more information on the impact of seawater salinity on ultrastructure of chloroplasts and oleosomes in relation to fat metabolism in flag leaves of two wheat cultivars during grain-filling.

**Impact of Seawater Salinity**

**Growth vigor, water relations, protein and nucleic acids**

In general, sea water at 10% and 25% caused noticeable reduction in root/shoot ratio, root density, root distribution, flag leaf area and specific leaf area as well as in the degree of succulence and sclerophyll during grain filling. Furthermore, seawater at 10% and 25% caused noticeable reduction in almost all growth criteria that was consistent with the progressive alteration in water relations (RWC & SWD), protein and nucleic acids (DNA and RNA) content of both varieties during grain filling. The magnitude of reduction was more obvious at higher salinity levels than the lower one particularly in Gemmieza-9. Furthermore, reduction was more pronounced at the higher salinity levels as compared to the lower one, particularly in Gemmieza-9.

**Osmotic adjustment and osmylates**

Osmotic pressure (OP), osmotic adjustment (OA) and solutes accumulation (TSS, TSN, proline, organic acids, glycerol and inorganic ions (Na⁺, K⁺, Ca²⁺, Mg²⁺ and Cl⁻) were quantified in flag leaf during grain-filling (14 and 21 days post-anthesis). Seawater salinity induced significant increase in osmotic pressure and the magnitude of increase was higher in Sids-1 than in Gemmieza-9. Furthermore, seawater concentrations caused noticeable increase in osmotic adjustment, organic solutes (TSS, TSN, proline, organic acids and glycerol) and inorganic ions (Na⁺, K⁺, Ca²⁺, Mg²⁺ and Cl⁻). On the other hand, decrease in K⁺/ Na⁺ ratio in the flag leaves of both cultivars was observed. The capacity of osmotic adjustment was greater in younger leaves than in older ones particularly with higher concentration (25%) in both cultivars. Moreover, the production of both organic and inorganic ions tended to be higher in Sids-1 than in Gemmieza-9. Gemmieza-9 appeared to be more sensitive than Sids-1. Osmotic pressure of flag leaf sap appeared to depend mainly on proline, TSN, TSS, organic acids, glycerol and...
Ions content, where there is a positive correlation between osmotic pressure and all of them.

**Photosynthesis and Ultrastructure Characteristics**

Chloroplast ultrastructure, chloroplasts number, pigment content and photosynthetic activity were quantified during grain-filling (14 and 21 days post-anthesis) of two wheat cultivars (salt sensitive cultivar, Gemmieza-9 and salt tolerant cultivar, Sids-1) subjected to different seawater at percentage 10% and 25%. The results showed that there were slight differences between the two cultivars in response to seawater at 10% and 14 days post-anthesis in terms of chloroplasts ultrastructure. The most obvious changes were observed with the treatment with 25% seawater at 21 days post-anthesis. Moreover, disorganized membrane system was identified with swollen thylakoids and many plastoglobuli were recognized in the chloroplasts in comparing to control plants. Number of chloroplasts was subsequently decreased with increasing seawater concentrations in both cultivars and the reduction was higher in Gemmieza-9 than in Sids-1. Furthermore, the applied concentrations of seawater induced noticeable reduction in pigments content (i.e. Chl a, Chl b, Chl (a+b), Chl (a/b), carotenoids and anthocyanin) as well as in photosynthetic activity (i.e. soluble, insoluble, total photosynthates and ratio of soluble/insoluble photosynthates in both cultivars and this reduction tended to be higher in Gemmieza-9 than in Sids-1). The changes in pigments content and photosynthetic activity of flag leaf appeared to depend mainly on chloroplasts ultrastructure and its numbers, where there is a positive correlation between chloroplasts number and pigments content.

Furthermore, numerous spherical oleosomes were observed as free in the vacuole of flag leaf cells of both untreated and seawater treated plants. Oleosomes appeared to have a sharply-defined osmiophilic interface and apparently lack a limiting membrane. Furthermore, there was a noticeable decrease in oleosomes volume in seawater-stressed flag leaves of both wheat cultivars from 14 to 21 days post-anthesis. Seawater irrigation induced a progressive increase in lipase activity and glycerol content in flag leaf of both cultivars during grain-filling. The tolerant cultivar accumulated more glycerol than sensitive one under salt-stress.

**Membrane Characteristics and Antioxidant Enzymes**

Seawater increased the malondialdehyde content in both wheat cultivars as compared to control plants, the increase being significantly higher in Gemmieza-9 than in Sids-1. The lower level of lipid peroxidation in Sids-1 probably indicated better protection against oxidative damage caused by seawater. Concomitant, the two applied concentrations of seawater reduced membranes stability resulting in an increased membrane leakage. Gemmieza-9 was characterized by the highest degree in membrane leakage and the lowest value of the membrane stability index. The activity of the antioxidant enzymes catalase, peroxidase and ascorbic acid oxidase increased under seawater irrigation in both cultivars with a higher increase in Sids-1 than in Gemmieza-9. Therefore, Sids-1 (resistant cultivar) had a higher potential to withstand seawater stress than Gemmieza-9 (sensitive cultivar) (Figure 1).
Conclusion

This review discusses the impact of seawater salinity on morpho-biochemical, photosynthesis, ultrastructure of chloroplasts and oleosomes in relation to fat metabolism in flag leaf of two wheat cultivars during grain-filling. In conclusion, it is clear from this investigation that the impact of seawater irrigation at 10% or 25% on both wheat cultivars particularly sensitive one had a negative effect on growth vigor of root and shoot, leaf area expansion, pigments content, membrane stability, relative water content, protein content, DNA, RNA as well as ultrastructure of chloroplasts and oleosomes of flag leaf during grain filling. On the other hand, seawater stress resulted in accumulation of inorganic ions, organic solutes, glycerol and saturated fatty acids which in turn involved with cell protection and osmotic adjustment. In addition salinity induced plant defense machinery with varying degrees in both wheat cultivars by enhancing the activity of antioxidant enzymes [24-32].

References

1. Joseph B, Jini D, Sujatha S (2010) Biological and physiological perspectives of specificity in abiotic salt stress response from various rice plants. Asian Journal of Agriculture 2: 99-105.
2. Mahajan S, Tuteja N (2005) Cold, salinity and drought stresses. An Arch Biochem Biophys 444(2): 139-158.
3. Malorgio F, Incrocci L, Carmassi G, Pardossi A, Tognoni F (2001) Accumulo di salt (NaCl) e consumo minerale in pomodoro cultivato in sistemi idroponici a ciclo chiuso. Italus Hortus 8: 43-48.
4. Hajlaouia H, Ayebb N, Garrecc JP, Dendend M (2010) Differential effects of salt stress on osmotic adjustment and solutes allocation on the basis of root and leaf tissue senescence of two silage maize (Zea mays L.) varieties. Industrial Crops and Products 31: 122-130.
5. Neocleous D, Vasilakakis M (2007) Effects of NaCl stress on red raspberry (Rubus idaeus L. and Autumn Blis L). Scientia Horticulturae 112: 282-289.
6. Ottow EA, Brinker M, Teichmann T, Fritz E, Kaiser W, et al. (2005) Populus euphratica displays apoplastic sodium accumulation, osmotic adjustment by decreases in calcium and soluble carbohydrates, and develops leaf succulence under salt stress. Plant physiology 139: 1762-1772.
7. Alves AAC, Setter TL (2004) Abscisic acid accumulation and osmotic adjustment in cassava under water deficit. Environmental and Experimental Botany 51: 259-271.
8. Khan NA, Syed S, Masood A, Nazar, R, Iqbal N (2010) Application of salicylic acid increases contents of nutrients and antioxidative metabolism in mungbean and alleviates adverse effects of salinity stress. International Journal of Plant Biology 1: 1-8.
9. Liu X, Huang B (2008) Photosynthetic acclimation to high temperatures associated with heat tolerance in creeping bentgrass. J Plant Physiol 165(18): 1947-1953.
10. El-Nahry AH, Hammad AY (2009) Assessment of salinity effects and vegetation stress, West of Suez Canal, Egypt using remote sensing techniques. Journal of Applied Sciences Research 5: 316-322.
11. Azoze MM, Hassanain AM, Faheed FA (2002) Riboflavin (vitamin B) treatments counteract the adverse effects of salinity on growth and some relevant physiological responses of Hibiscus sabdariffa (L.) seedlings. Bulletin of Faculty of Science, Assiut University 31: 395-303.
12. Alesuquy HS, Gaber AM (1993) Effect of growth regulators on Vicia faba plants irrigated by sea water. Leaf area, pigment content and photosynthetic activity. Biologia Plantarum 35: 519-527.
13. Werker E, Lerner HR, Weinberg R, Poljakoff-Mayber A (1983) Structural changes occurring in nuclei of barley root cells in response to a combined effect of salinity and ageing. American Journal of Botany 70: 222-225.
14. Naidoo G, Hirai O, Naidoo Y (2011) Hypersalinity effects on leaf ultrastructure and physiology in the mangrove Avicenniarmarina. Flora - Morphology, Distribution, Functional Ecology of Plants 206(9): 814-820.
15. Bergfeld R, Hong YN, Kithni T, Schofer P (1978) Formation of oleosomes (storage lipid bodies) during embryo genesis and their breakdown during seedling development in cotyledons of Sinapis alba L. Planta 143(3): 297-307.
16. Khan MH, Panda SK (2008) Alterations in root lipid peroxidation and antioxidative responses in two rice cultivars under NaCl-salinity stress. Acta Physiologicae Plantarum 33(3): 811-822.
17. Munns R, Tester M (2008) Mechanisms of salinity tolerance. Annu Rev Plant Biol 59: 651-681.
18. Arora N, Bhardwaj R, Sharma P, Arora HK (2008) 28-Homobrassinolide alleviates oxidative stress in salt-treated maize (Zea mays L.) plants. Brazilian Journal of Plant Physiology 20: 153-157.
19. Joshi PK, Saxena SC, Arora S (2011) Characterization of Brassica juncea antioxidant potential under salinity stress. Acta Physiologicae Plantarum 33(3): 811-822.
20. Nichols DS, Olley J, Garda H, Brenner RR, Mcmeekin TA (2000) Effect of temperature and salinity stress on growth and lipid composition of Shevanellageldimarina. Appl Environ Mic robicol 66(6): 2422-2429.
21. XU X, Beardall J (1997) Effect of salinity on fatty acid composition of a green microalga from an antarctic hypersaline lake. Phytoc hemistry 45: 655-658.
22. Ivanova A, Nechev J, Stefanov K (2006) Effect of soil salinity on the lipid composition of halophyte plants from the sand bar of pomorie. General Botanica 58: 222-225.
23. Kabir ME, Karim MA, Azad MAK (2004) Effect of potassium on salinity tolerance of mungbean (Vigna radiate L Wilczek). Journal of Biological Science 4: 103-110.
24. Kholova J, Sainam RK, Meena RC, Srivastava GC (2009) Response of maize genotypes to salinity stress in relation to osmolytes and metal ions contents, oxidative stress and antioxidant enzymes activity. Biologia Plantarum 53(2): 249-256.
25. Munns R, James RA, Läuchli A (2008) Mechanisms of salinity tolerance. Annu Rev Plant Biol 59: 651-681.
26. Musyimi DM, Netondo GW, Ouma G (2007) Effect of salinity on gas exchange and nutrients uptake in avocados. Journal of Biological Science 7(3): 496-505.
27. Sheldon A, Menzies NW, Bing SH, Dalal R (2004) The effect of salinity on plant available water. Supersoil 3rd Australian New Zealand Soils Conference, 5-9 December, University of Sydney, Australia.
28. Siddiqui ZS (2006) Biochemical responses of dimorphic seeds of Arthrocnemum indicum (L. Willd) during germination, inhibition, and
alleviation under saline and non-saline conditions. Turkish J Biol 30: 185-193.

31. Welch ME, Rieseberg LH (2002) Habitat divergence between a homoploid hybrid sunflower species, Helianthus paradoxus (Asteraceae), and its progenitors. Am J Bot 89(3): 472-479.

32. Welch ME, Rieseberg LH (2002) Patterns of genetic variation suggest a single, ancient origin for the diploid hybrid species Helianthus paradoxus. Evolution 56(11): 2126-2137.