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Review Article

Plants Under Salinity Stress: A Physiological And Antioxidant Resistance Scheme.

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Abstract

Global food output is being negatively impacted by salinity, which is regarded as a major abiotic constraint. Numerous studies have been conducted to identify the methods by which plants tolerate salt stress, and the results have shown some key enzymes and altered biochemical processes that may be responsible for agricultural plants' resistance. Studies that have been carried out for the last tanners ordinarily have observed the development of salt tolerant cultivars via traditional means, as well as extemporized by modern epoch molecular tools and techniques. Environmental stresses considerably and notably affect the productivity of plants in several ways. Generally, plant growth and development is greatly affected by the process of osmotic stress under soil salinity and Na^+ and Cl^- ions are toxic as well as having injurious effects that results in the imbalance among $SO4^{2-}$ and Mg^{2+} ions as well as significant nutrient elements in plants. As a number of mechanisms reveal the salinity stress response as well as salinity tolerance processes, the effect is called polygenic which includes beneficial compatible solutes or osmolytes, polyamines, reactive oxygen species (ROS) as well as antioxidant defensive processes, transport and compartmentalization of injurious toxic ions. In order to identify the cue factors regarding the particular retaliations or cumulating toxic ions, it is crucial to understand the whole process accountable for growth restriction as well as retarding production of plants with the further span of retaliating the same. The present review will try to summarize the physiological as well as antioxidant defense mechanisms in plants upon salt toxicity. Explaining salinity tolerance as well as its later perspectives and applications in screening for salt tolerance will also be a venture of the present study.

Keywords : Salinity stress; Toxic ions; ROS; Antioxidants; Salinity tolerance.

INTRODUCTION

In general, the quality and quantity of world agricultural production are greatly diminished by environmental stresses (de Cássia et. al. 2018, Gharsallah et. al. 2016, Foolad 2007, Karan and Subudhi 2012). Besides, 71% crop yield reduction is occurring by abiotic stresses (Ashraf *et al.,* 2010). According to numerous estimation the probable yield reductions are 17% due to drought, 20% due to salinity, 40% due to high temperature, 15% due to low temperature, and 8% due to other factors (, Ashraf & Harris, 2005). Approx. 20 % of irrigated land are affected by the soil salinity which terms as a global complication that both affects and drops crop yields remarkably (Qadir et al., 2014). Most notably, natural salinity and human interferences continuously transforming the arable land is into saline which is anticipated to deluge global effects, that consequence up to 50% land drop within 2050 (Saha *et al.,* 2010; Hasanuzzaman *et al.,* 2013). Salinity stress sometimes called 'Secrete Murder' as it destroys plants and other organisms grown on it. 'White Death' also used as synonym of it describing white images of lifeless shining lands studded with dead trees. Salinity is one of the most serious problems eradicating global agricultural production (Foolad 2007, Gharsallah al. 2016, Foolad 2007, Karan and Subudhi 2012). It is claimed that, worldwide, 800 million ha of land and 32 million ha of agricultural land are salt-affected (FAO 2015). The closest areas to the seashore are more prone to salinity where salinity reduces agricultural productions to a large scale. Salt problem in agricultural crops, commonly develops in the irrigated areas where salts from the irrigation water build up in the root zone. Irrigated land occupied about 17% of global cultivated land, which merely accords

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30% of total crofter production (Hillel, 2000). Crop cultivation under irrigated land is enhancing day by day, which results enhancement of salinity of these lands, creating a major upset for global food reliability. The extremity of Salinity stress inhibits crop production by changing numerous physiological and metabolic activities [Souid et. al. 2018, R. A. James et.al, 2011, A. Rahnama et. al , 2010, Munns, 2005, Rozema et.al, 2008]. Tremendous reduction in Plant growth and yield is caused by several manners under salinity stress.

Sodium Chloride presents as vast percentage in nature playing dominant roles in affecting natural plant production mainly in two consecutive manners: osmotic stress and ionic toxicity. Osmotic pressure occurred more in plant cells compared to surrounding soil solution in absence of salts in soil. On the other hand, osmotic pressure exceeds in soil solution than plant cells under salnity which limits plants ability to absorb water and minerals like K^+ and Ca^{2+} (Glenn, Brown & Khan, 1997; Munns, James & Läuchli, 2006). As Na^+ and Cl^- has the ability to draw up directly into the cells creating toxic effects on cell membranes, so on the metabolic cytosolic activities (Greenway and Munns, 1980; Hasegawa *et al.,* 2000; Zhu, 2001).

Reduced cell expansion, assimilate production and membrane function, as well as decreased cytosolic metabolism and production of reactive oxygen intermediates (ROSs) are considered as some secondary effects of salinity. Even extremity of salinity can results in plant death. Few plants are able to fight against salinity as well as related stresses by several external and internal mechanisms to evade internal water loss through dehydration and stimulation of sufficient water uptake, amend leaf architecture, amplified extent of assimilates owed to roots, reduced the rate of limb proceeds and developmental rates, dormancy as well as osmotic amendment, etc. (Chaves et al. 2003).

Plants with deep root system, ability to reserve more water-soluble carbohydrates at the base of tiller as well as fast nitrogen uptake, are some superior characters relevant to salt tolerance has been observed in perennial forage grasses in the south of France (Volaire et al. 1998).

Generally, amassing of solutes with low molecular weight as well as inorganic ions are superficial osmotic acclimatizing events to abolish osmotic hazards of the tissue (Gagneul *et al*. 2007, Ahmad *et al.,* 2010a; Ahmad *et al.,* 2010b; Ashraf & Foolad, 2007; Devi & Prasad, 1998; Foyer *et al.,* 1994). A number of plants in addition to halophytes are able to withstand ion toxicity and sufficient water uptake of even under extremity of salinity (Munns 2002). Osmotic adjustment stabilizes metabolic processes in tissue as well as also enables regrowth upon rewetting (Morgan 1984).

SALINITY AS A MAJOR CURTAILMENT TO PLANTS

Generally, soil salinity can be occurred and exert its influence on plants in two processes: first present of a high concentration of salts in the soil, that converts it unable for roots to absorb water (osmotic stress), as well as prominence in a high percentage of toxic salts within the plant (ion toxicity). In the outer surface of roots, salts cause reduction of cell growth and metabolism; although, accumulation of toxic salts requires time to exert into plants and after that they become able to affect plant functions (Hasanuzzaman *et al.,* 2013, Munns & Tester, 2008, Gharsallah al. 2016, Foolad 2007, Karan and Subudhi 2012).

The physiological performances of crop plants are considerably as well as adversely affected by salt stress imposition that even turn plant to death as a result of a drastic reduction of growth also due to injury in the metabolic activity(Hasanuzzaman *et al.,* 2013, Gharsallah al. 2016, Foolad 2007, Karan and Subudhi 2012). Usually, the nature of plants, plant species, duration, stage, concentration, as well as mode of salt application to the crops, all are considered as essential factors for estimating the intensity and diminishing effects of salinity to the plants (Dugasa et. al. 2018).

Soil salinity is considered as a serious drastic abiotic stress as it reins majority of crops grown worldwide (Gharsallah al. 2016, Foolad 2007, Karan and Subudhi 2012). Irrigation system and removal of plants from lands may be a reason for it with many other well-known anthropogenic causes (Munns et.al 2008). About 20% of total global cultivable land are now under salinity affected, drastically harassing agricultural production and now it has become a more prominent universal issue (Flowers & Yeo, 1995). Accumulation of dissolved salts within the soil or irrigation water to a harmful concentration causes reduction of plant growth and development referred as salinity stress (Gorham, 1992). Plant growth and developments are largely governed by several physiological processes which are mostly inhibited under salinity needed to be properly scrutinized to understand tolerance mechanisms in plants under salinity (Asgari, 2012). Aggregation of Salts is increased to an extreme level to the plants root zone causing salinity-induced stress (Zhang *et al.,* 2012). For this, reduction in water uptake from soil surface creates water stress, while sufficient water present in the root zone. Water absorption of saline soils requires an extra energy expenditure. Thus, higher salinity will always lead to decreased levels of water as well as inducing analogous stresses like water and osmotic stress (Bauder & Brock, 1992).

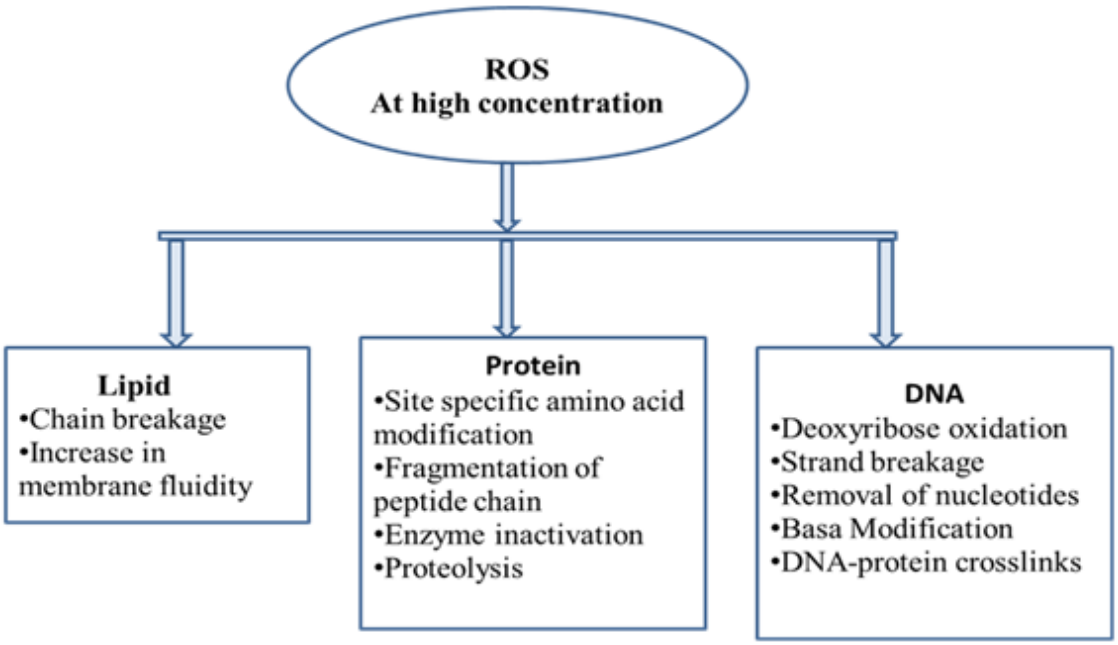
High osmotic pressure is created by the high salt concentrations in soil limits water uptake by seeds (Khan & Weber, 2008), responsible for the metabolism of nucleic acid digestion (Gomes-Filho et al., 2008), metabolism of protein changes (Dantas et al., 2007) as well as hormonal offset are

aggravated (Khan & Rizvi, 1994), results in the destruction of the ability to utilize seed stores (Othman et al., 2006). There are also varying intramural (plant) and external (natural) processes influencing seed germination under saline conditions incorporating the nature of seed layer, seed torpidity, seedling power, seed polymorphism, seed age, water, gases (Mguis et al., 2013), light and temperature (Wahid et al., 2011). Higher concentrations of the salt results hyper ionic and hyperosmotic stress, even cause's death of the plant. Membrane layer harm, nutrient unevenness, distorted levels of enzymatic hindrance, developmental regulators and metabolic abnormality, including photosynthesis, which at last prompts plant demise may be occurred from the impact of salinity (Hasanuzzaman et al., 2012; Mahajan & Tuteja, 2005).

Na^+ and Cl^- ions are the most deleterious for plants under salinity (Tavakkoli et al., 2010). Several complex processes such as photosynthesis is also affected by the biotic as well as abiotic stresses influencing various major components like photosynthetic pigments, photo systems, the electron transport system, CO_2 reduction pathways, etc. All kinds of Stresses can affect any of these components, reducing the photosynthetic capacity of plants. Utilization of protein kinases, for example MAPKs and transcription factors are most important to eliminate this harm (Ashraf et al., 2013; Saad et al., 2013; Zhang L et al., 2012).

Importance of ion exchange during salinity on the facilitating plant development has observed by Rajendran et al. (2009). They have observed accumulation of hazardous ions after 2–4 weeks of exposure of salt stress. The stress caused by ions (Na^+ and/or Cl^-) overlaps with the osmotic impacts and demonstrates more hereditary variety than osmotic impacts (Dugasa et. al. 2018, Munns et al., 2002).Reactive oxygen species (ROS) induced oxidative spoil to lipids, proteins, in addition to DNA. The cellular hurt takes place in different ways. (Choudhury et. al., 2017, Mursu et al., 2008; Souid et. al. 2018, R. A. James et.al, 2011, A. Rahnama et. al , 2010, Munns, 2005, Rozema et.al, 2008).

Figure 1. Effects of ROS at high concentrations on plants under salinity stress.



PLANT SPECIES HAVING DIVERSE POTENTIALS UNDER SALINE ENVIRONMENT

Plants are classified as halophytes and glycophytes according to their relevant capacity to sprout under salinity. Halophytes have the intrinsic ability to grow and survive till the entire life cycle under saline environment (around 500 mm NaCl) (Zeng et. al. 2018, Colmer, Flowers & Munns, 2006). On the contrary, Glycophytes are unable to sustain at extreme salt concentration, so also known as non-halophytes. The majority of cultivable crops are glycophytes, but few of them like sugar beet, barley; wheat, etc. has ability to cope with salt to some extent. From another point, halophytes are able to accumulate toxic salts in the leaves in spite of the internal parts to avoid injury as plants are not able to possess a high concentration of salts except slashing (Zeng et. al. 2018, Volkmar *et al.,* 1998). And therefore, these consequences suggest different strategies relating the adaptive mechanisms of halophytes and glycophytes in a distinct manner. Usually halophytes are not able to survive at high level of salinity without balancing the concentrated salt ions as osmoticant materials to some extent. For lack all the above trivial processes, glycophytes are not able to survive in saline conditions whereas halophytes survive. But both the glycophyte and halophyte are equally sensitive to salts if we want to study some sensitive processes like photosynthesis and respiration (Volkmar *et al.,* 1998) under salinity.

RETALIATIONS UNDER SALT STRESS (PHYSIOLOGICAL AND OXIDATIVE VIEWS)

Ion homeostasis including compartmentalization, efficient ion transfer and uptake, stimulation of biosynthesis of osmo protectants as well as companionable solutes, inauguration of antioxidant enzyme and synthesis of antioxidant compounds, synthesis of polyamines, production of nitric oxide (NO), and hormone inflection are numerous physiological and biochemical phenomena occurring in plants to withstand extremity of salinity. Several exploration advances elucidating these mechanisms are discussed below.

Sustaining ionic equanimity

Some studies reported that adaptive processes of plants under salinity can be elucidated from two points, (1) on the basis of the leaf Na+ concentration and also (2) on the ability of the plant to maintain high cellular Na+ levels (Dugasa et. al. 2018, García-Caparrós et. al. 2018, Shabala and Cuin, 2008). For this, Na/K ratio for both roots and shoots have to be accounted in all cases; although, the ratio is mainly influenced by changing the Na+ concentration, that always posses much greater proportion in comparison to the K+ ion concentration.

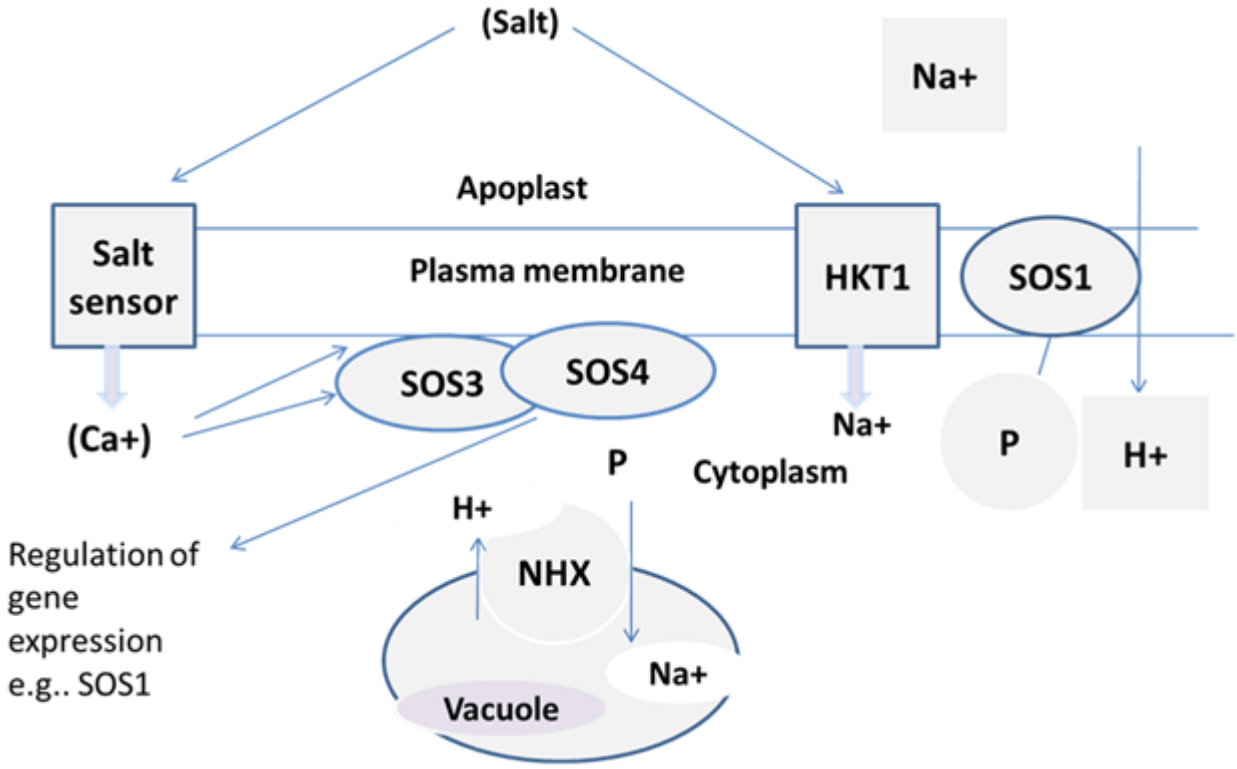
The efficiency to uptake crucial ions and their subsequent deliberation, both are fundamental events that require for appropriate growth and development of plants both under normal in addition to salinity (Nikalje et. al., 2018, García-Caparrós et. al. 2018, Niu Xiaomu et. al 1995, Serrano et. al. 1999, Hasegawa, 2013).

The most available form of salt of soil is NaCl, therefore researches needs to be more advanced to comprehend subsequent uptake and convey of Na+ ion within plant body in salinity. The ultimate storage of Na+ ion normally is vacuole where it transported from cytoplasm via Na+/H+ antiporter. Vacuolar type H+-ATPase (V-ATPase) and the vacuolar pyro-phosphatase (V-PPase), are two fundamental forms of H+ pumps of vacuole (Dietz, et.al. 2001, De Lourdes et. al. 2001, and Wang et. al. 2001).

SOS_1, SOS_2 as well as SOS_3 are three crucial proteins in the SOS (Salt Overly Sensitive) signaling pathway also referred as stress signalling pathway in the process of ionic equability and enable plants to survive under salinity.

SOS_1 plays an important role in the ion homeostasis through balanced efflux of Na+ ion at cellular level and also in the stimulation of long space convey of Na+ ion from root to shoot. So, higher concentration of this protein stimulate plants tolerance under salinity(Hasegawa et.al. 2000, Sanders et. al. 2000, Shi et. al. 2000, 2002).

Figure 2. Regulation of ion homeostasis by the SOS pathway during salt stress.



(Source: Nikalje et. al., 2018 , Hasegawa et.al. 2000, Sanders et. al. 2000)

Salt stress-induced Ca^{2+} signals are perceived by SOS3 which activates the SOS2 kinase. The SOS3±SOS2 kinase complex regulates cellular Na + levels by stimulating Na + transport out of the cytoplasm (e.g. By increasing the expression and activity of SOS1) and conceivably by restricting Na + entry into the cytosol (e.g. inhibiting HKT1 activity). An additional target of the SOS2 kinase, NHX (vacuolar Na + /H + exchange), also contributes to Na + ion homeostasis by transporting Na + from the cytoplasm into the vacuole.

High and low-partiality K+ transporters (HKT)

Several approaches help to keep ionic concentration in a balanced level in the cytoplasm (Ahmad *et al.,* 2010a; Ahmad *et al.,* 2010b; Ashraf & Foolad, 2007; Devi & Prasad, 1998; Foyer *et al.,* 1994). K^+ ions play a key regulatory role in promoting Na^+ exclusion in plant metabolic process and thus promote the process of osmotic adjustment (Dugasa et. al. 2018, García-Caparrós et. al. 2018, Souid et. al. 2018, Chakraborty et al. 2016). Associated components of membranes usually take part as a crucial role in order to maintain ion concentration in balanced form inside the cytosol under the stress condition for ultimate regulation of ion uptake and transport (Sairam et. al. 2004). The transport phenomenon is carried out by different carrier proteins, channel proteins, antiporters and symporters. Maintaining cellular Na+/K+ homeostasis is pivotal for plant survival in saline environments (R. Munns et. al. 2008, Sairam et. al. 2004, Oh, D.H, et. al. 2010). For appropriate cytoplasmic enzyme activities, it is essential to keep a high concentration of cytosolic K+ which accounts for about 100mM regarded as ideal. The ranges of K+ concentration vary between 10mM and 200mM within the vacuole (R. Munns et. al. 2008, Sairam et. al. 2004, Oh, D.H, et. al. 2010). Vacuole possesse most important and largest plunge of K^+ in the plant cell. In order to maintain the turgor within the cell, undoubtedly K^+ has a crucial role (R. Munns et. al. 2008, Sairam et. al. 2004, D.-H. Oh, et. al. 2010) that is usually conveyed into the plant cell as opposed to the concentration gradient via K^+ transporter and membrane channels. K+ transporters are mediated for K^+ uptake mechanisms and possesse relatively high affinity when the concentration of K^+ ions are lower outside the cells, on the other hand reverse or low affinity uptake is carried out by K^+ channels when the concentration of K^+ ions are relatively higher outside the cells,. Availability of K^+ ions in the soil can be primarily used to determine the uptake mechanism whereas, very low concentration of Na^+ ion (about 1mMor less) usually maintained in the cytosol. As Na^+ concentrations are high during salinity stress, it combats with K^+ ions during transportation as they are associated with the same transport mechanism and therefore, usually K^+ ions decreased (Dugasa et. al. 2018, R. Munns et. al. 2008, Sairam et. al. 2004).

Two classes of HKT family take part either as particular Na^+ and K^+ co-transporters or Na^+ transporters (Hauser & Horie, 2010; Shabala et al., 2010). Improvement of Na^+ uptake and higher Na^+ levels in xylem sap (salt including conduct) was demonstrated by HKT21 to ameliorate that are analogous with prolonged salt tolerance (Mian et al., 2011a). Na+ avoidance from the shoot is connected with salt tolerance and that genes from the HKT1 subfamily, for example, HKT1;4 and HKT1;5, are included (James et al., 2011; Munns et al., 2012). Shabala et al. (2010) demonstrated that salt exclusion and deliberation both are pivotal for salt tolerance in grain. Actually, grain is an erect demonstration of a harvest which associates halophytic as well as glycophytic belongings, accordingly, both the glycophytic and holophytic components that might be used to adapt to salt stress (Mian et al., 2011b) may be an outstanding model to study.

OSMOTIC ACCLIMATIZATION

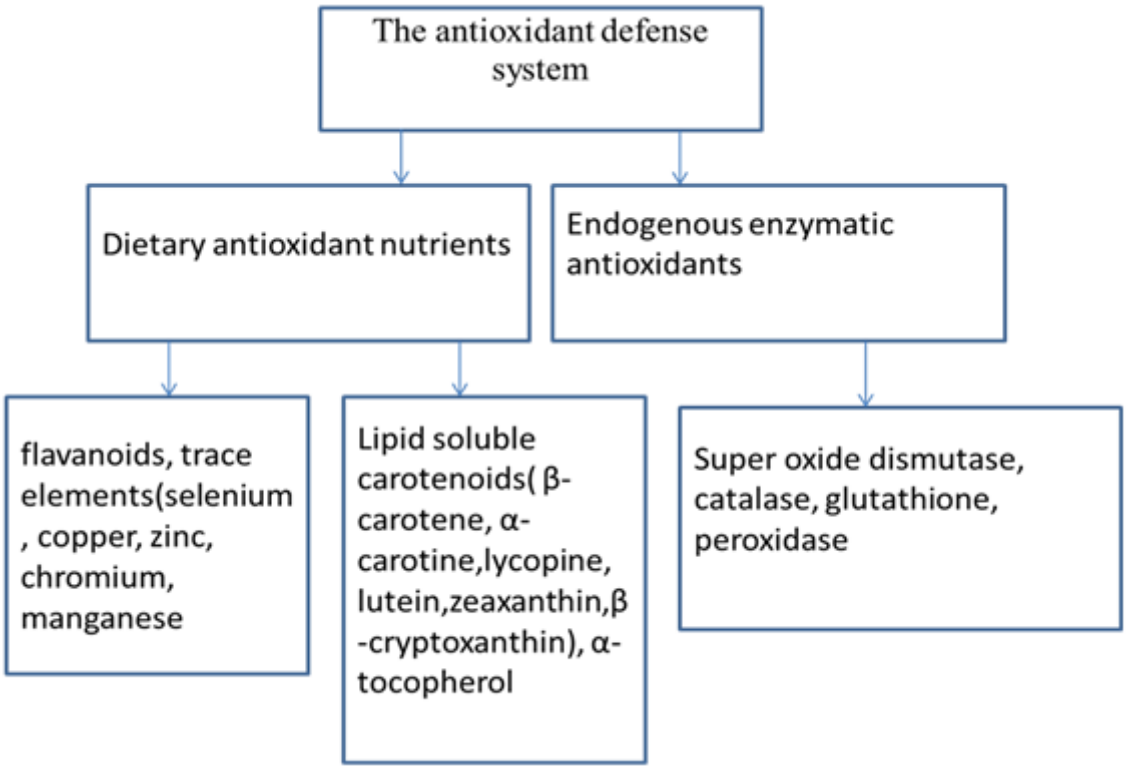
Several mechanisms assist to fight against disruptive and harmful effects of both primary and secondary stress with the augmentation of osmolytes and antioxidant production (Choudhury *et. al.,* 2017, Ahmad *et al.,* 2010a; Ahmad *et al.,* 2010b; Ashraf & Foolad, 2007; Devi & Prasad, 1998; Foyer *et al.,* 1994; Geebelen et. al., 2002). Compatible solutes such as glycine betaine, proline and poles, etc. which are generally accumulated in the cytoplasm and essential for decreasing water potential occurring in the vacuole and ultimately to make a balance during the ion accumulation in that compartment (García-Caparrós et. al. 2018, Souid et. al. 2018, dos Reis et al., 2012). According to several studies, Salinity stress generally increases compatible organic solutes; however, whether a greater increase in compatible solutes correlates with increased salinity tolerance in plants remains to be shown. For barley, at least, it appears that the more salt-tolerant varieties accumulate less compatible solutes than do the more sensitive varieties (Chen et al., 2007, Mahdavi et. al. 2013).

- Salt ions compartmentalization betwixt the cytoplasm and vacuole provides a strict osmotic gradient across the vacuolar membrane. A Stabilizing process known as osmotic adjustment maintains this flow by an enhancement of the synthesis of chemical and biochemical molecules in the cytoplasm,. As a vital mechanism, Osmotic adjustment is utilized by plants as to fight against salt stress (Pessarakli, 2014, Zhang et al. 2002a). In osmotic adjustment both organic solutes and inorganic ions have a pivotal contribution varying among the captivars, species as well as even among same plant occupying separate positions (Ashraf and Bashir 2003, Ashraf and Foolad 2007). Low molecular weight solutes

such as the organic osmolytes traditionally generated in higher plants: sugar and sugar derivatives, such as sucrose, polyols, and heterosides; methylated tertiary N compounds, such as glycine betaine and homarine; amino acids such as proline and glutamate and other low molecular weight metabolites (Jakobsen et al. 2007). Organic osmolytes posses a versatile role in performing osmotic as well as saving sub cellular structure which regards as a central dogma in stress physiology (Hare et al. 1998). Uptake of inorganic ions and osmotic solutes plays as a substitute source compared to the synthesizing organic solutes in plants (Gagneul et al. 2007). Osmotic stress is also experienced in other photosynthetic organisms, considerably in algae mediates similar responses and tolerance mechanisms as higher plants (Chapin 1991). Such as similar compatible solutes (e.g., proline, glycerol, and betaine) are found to be assembled by a unicellular green alga *Dunaliella salina* (Chlorophyta) and higher plants under salt stressed condition (Zhang et al. 2002b). Proline, glycine-betaine, proline betaine, B-alaninebetaine, D-sorbitol, D-mannitol, sucrose, glucose, fructose, D-pinitol, L-quebrachitol, Myo-inositol, b-dimethylsulphone and propionate are compatible solutes utilized by plants in osmotic adjustment mechanisms (Lauchli & Epstein, 1990).

- The antioxidant defense system comprises endogenous enzymatic and exogenous non enzymatic nutrients (Lira et. al. 2018, Choudhury et. al., 2017, Souid et. al. 2018, Zhu et al. 2003). The dietary antioxidant nutrients can either be water soluble or lipid soluble. There are also other dietary constituents that may have either direct antioxidant activity or indirect antioxidant activity such as trace elements that are constituents of antioxidant enzymes (Dugasa et. al. 2018, Alissa et. al. 2012).

Figure 3. The antioxidant defense system (Source: Alissa et. al. 2012, Lira et. al. 2018).



Due to expecting compatibility with cytoplasmic entities and processes, normally 'compatible solutes' is occasionally used to narrate these organic osmolytes (Munns & Tester, 2008). As an instance, in tobacco proline synthesis plants expand up to 80 times under saline environments.

- Proline is considered as a key amino acid that assists plants to resist osmotic stress (Lira et. al. 2018, Souid et. al. 2018, Rajaravindran et. al. 2012). Generally proline level increases with the consecutive increasing of L-glutamic acid concentration in plants under stresses, hence it is considered as one of the possible precursors for proline biosynthesis(Souid et. al. 2018, Ashraf and Foolad 2007; Kishor et al. 2005, Willekens et al. 1997, Ray et. al., 2016, Rajaravindran et. al. 2012).Various studies reported that the accumulation of proline in a wide variety of species under various kinds of stresses and its possible involvement in adaptive mechanisms (Ray et. al., 2016, Lee *et al.* 2013, Azad *et al.* 2012, Marvi *et al.* 2011, Zhang *et al.* 2014, da Costa et. al. 2011, Arshi *et al.* 2012, Turan *et al.* 2012) . Proline scavenges free radicals to mediate osmotic adjustment as well as stabilizes sub cellular structures (Hare and Cress 1997). For example In durum wheat (*Triticum aestivum L.*), a positive interaction was observed between proline level and osmotic potential, and thus it was suggested that proline is

a crucial metabolite in osmotic adjustment under salinity stress (Poustini et al. 2007). Normally proline accumulates in the cytosol in plants as well as it serves as major factor to the cytoplasmic osmotic adjustment in corresponds to drought or salinity stress (Ashraf and Foolad 2007).

- Glycerol usually emulsed from glucose, serves as principle osmolytes in some plants as well as its rate of synthesis increases upon salinity falls up after which it converts to starch when salinity falls down (Chen and Jiang 2009). However, Glycerol can be an efficient osmolytes under high salinities as it is difficult to match the extreme solubility of glycerol with many other solutes which are compatible and it is chemically inert, so that also non-toxic (Ahmad et. al. 2018). Next, it is an end-product metabolite, and hence its occurrence is unlikely to offset of most of the metabolic processes. Fourth, the energetic cost of glycerol synthesis from glucose is comparatively low and availability of nitrogen doesn't a matter for it (Chen and Jiang 2009).
- Several sugars such as sucrose, trehalose, glucose and fructose, etc. are the major osmolytes in many plants which are associated with osmotic adjustment. Generally NaCl treatment causes an increase in total sugar content in plant cells, hence the sugar content regarded as a very sentient factor regarding the salt tolerance improvement (Liu and van Staden 2001). Digression of sugars associated with NaCl-tolerance, such as NaCl and Cl– translocation and (or) compartmentalization, solute synthesis for interdependent mechanisms of growth and osmotic adjustment, and protein turn-over Sugars, all play a bit part in the adaptative processes (Liu and van Staden 2001). Sugars are most commonly found to accumulate under osmotic stress in most of the plants. For instance the total soluble sugar level in a salt-tolerant rice variety was more than in the salt-sensitive variety, and thus sugars contribute to the resistance mechanisms to salt-induced osmotic stress in rice plants (Cha-um et al. 2009). Another study revealed that, in root nodules of legumes (*Medicago truncatula* and *Phaseolus vulgaris*), the synthesis and accumulation of trehalose was greatly increased as a compatible solute which causes resistancy to salt stress (Lo´pez et al. 2008). Sorbitol is the principle low molecular weight carbohydrate and found to be increased with the extremity of salinity and possesse essential role in the osmotic adjustment as an osmolytes or compatible solute (Eggert et al. 2007a). Another study claimed as mannitol is the main low molecular weight carbohydrate which also observed to be increased upon salinity in red alga *Dixoniella grisea* (Rhodellophyceae) and claimed to be posses major osmotic functions in the red alga that is unicellular (Eggert et al. 2007b).
- The concatenation of glycine betaine in promoting salinity tolerance has been enumerated in barley and maize (Volkmar et al., 1998) and also verified by several studies from genetic field. Betaines are generally carry a fixed positive charge upon the fully methylated nitrogen atom and are ammonium compounds (Zhang et al. 2002a) which is generally synthesized by many plant families when exposed to saline or drought stress (Munns 2002; Ashraf and Harris 2004; Su et al. 2006). The primary functions of betains is to keep the intracellular and extracellular ions in balanced form through counterbalancing the osmotic potential in order to scale down the toxic effects of salinity as well as also stabilizes the protein structures and play major functions in the protection of the major enzymes, membrane structures, photosynthetic apparatus, cytoplasm, chloroplasts from the toxicity of Na+ and thus regards as a compatible solute also (Raza et al. 2007). Glycine betaine has been also observed in sugar beet (*Beta vulgaris* L.) to be played a major osmolytic functions (Chołuj et al. 2008) during osmotic stress. Ashraf and Harris (2004) postulated that the most significant determinative of salt tolerance are sustaining as well as accumulating of both K+ and Ca2+, thus K+/Na+ and Ca2+/Na+ ratios can be an efficient and confirmative criteria for selecting salt tolerant crop species (Raza et al. 2007).
- Similarly Mannitol an important osmoprotectant in celery (Tarcynski et al., 1993). Notable extent of carbon is consumed by plants to produce sufficient osmotic substances and this process potentially restricts normal growth and development of the plant (Munns & Tester, 2008). Greater concentrations of inorganic ions also used for osmotic adjustment (Greenway & Munns, 1980).
- Synthesis of organic components in the cell expense more energy than this inorganic approach (Munns & Tester, 2008; Yeo, 1983). Generally, seven moles of ATP are needed in leaf cells, to aggregate one mole of NaCl as an osmoticum,. In contrary, the moles of ATP needed to synthesize one mole of an organic compatible solute are much more. The ATP requirement for the synthesis or accumulation of solutes has been estimated as 3.5 for Na+, 34 for mannitol, 41 for proline, 50 for glycine betaine, and approximately 52 for sucrose (Munns & Tester, 2008). Actually, accumulation of osmoticum, an powerful survival process for plants by adaptation under saline conditions although growth of the plant is greatly affected by it due to ion toxicity and deficiency this mechanism affected (Munns & Tester, 2008; Volkmar et al., 1998).
- Extreme salinity has been observed to stimulate ROS production and accumulation in plant cells (Chawla et al. 2013). Oxidative stress defenses occur through enzymatic antioxidant mechanism including catalase

(CAT), superoxide dismutase (SOD), peroxidase (POX) and enzymes of the ascorbate-glutathione cycle as ascorbate peroxydase (APX), monodehydroascorbate dehydrogenase (MDHAR), dehydroascorbate reductase (DHAR) (Dugasa et. al. 2018, Luis et. al. 2018, Foyer and Noctor 2011; Chawla et al. 2013) and non-enzymatic antioxidants as phenolics, flavonoids (Munne´-Bosch 2005; Gupta and Huang 2014; Rakhmankulova et al. 2015; Talbi et al. 2015).

- CAT generally found to be accelerated under salinity stress and associated to the salinity tolerance mechanisms which eliminates toxic levels of H_2O_2 and renders defense opposed to oxidative stress (Dugasa et. al. 2018, Sudhakar et al. 2001; Bor et al. 2003; Mittova et al. 2003; Mittova et al. 2004; Mittova et al. 2015; Gao et al. 2008 ; Chawla et al. 2013). CAT is involved in scavenging of H_2O_2 during salt stress and other abiotic stress conditions (Willekens et al. 1997, Ray et. al., 2016, Rajaravindran et. al. 2012, Ediga et. al. 2013, Kong-ngern *et al.* 2012, Khan *et al.* 2002, Ahmad *et al.* 2012, Van Breusegem et al. 2001; Shigeoka et al. 2002, Arshi *et al.* 2012) and is considered as a major enzyme detoxifying H_2O_2 in tomato fruits (Murshed et al. 2014).
- Although APX performs the same general function as catalase, it catalyzes the removal of H_2O_2 by using ascorbate as a reductant (Sudhakar et al. 2001; Bor et al. 2003; Mittova et al. 2003; Mittova et al. 2004; Mittova et al. 2015; Gao et al. 2008 ; Chawla et al. 2013) . APX is a family of isozymes widely involved in regulation of intracellular level of H_2O_2 in higher plants (Ray et. al., 2016, Rajaravindran et. al. 2012, Ediga et. al.2013, Kong-ngern *et al.* 2012, Khan *et al.* 2002, Van Breusegem et al. 2001; Shigeoka et al. 2002, Arshi *et al.* 2012).
- Several investigations proposed that H_2O_2 content as well as peroxidase enzymes that generally accumulate in the leaves can be valid criteria to measure the adaptability of crop plants towards salinity stress (Ediga et. al. 2013, Sajjad et. al. 2012, Weisany *et al.* 2012, Ozdemir *et al.* 2012, Shaheen *et al.* 2012).
- GPOX enzymes protect cells against oxidative damage generated by ROS. They catalyze the reduction of H_2O_2 or organic hydro peroxides to H_2O or alcohols. The second category comprises a series of regulatory proteins (transcription factors, protein kinases) involved in the regulation of the signalling cascade that controls the expression of additional genes whose products could belong, in turn, to either of the two groups (García-Caparrós et. al. 2018, Agarwal et al. 2006; Shinozaki and Yamaguchi-Shinozaki 2007)
- Sufficient water uptake requires maintaining an osmotic gradient and thus halophytic plants acquire inorganic ions to a concentration equal to or greater than that of the surrounding solution (Merchant and Adams 2005). In many plants, inorganic ions possess the crucial function in osmotic adjustment than that of compatible solutes and accumulation of organic osmolytes expenses more metabolic energy than sufficient uptake of ions from soil (Patakas et al. 2002).
- Mutant form of rsr1-1 found to be oversensitive to proline in Arabidopsis which can be suppressed by stockpiling of sugar like glucose or sucrose in the medium (Hellmann et al. 2000). So, there may be a straight correlation between proline metabolism as well as sugar-sensing mechanisms. Glycine betaine (5 to 50 mmol/L) found to be an important organic osmolytes to avert proline accumulation in oil seed of rape (Larher et al. 1996). The opposed effect of glycine betaine and the pragmatic consequence relied on glycine betaine uptake and accretion via a feasible osmotic upshot since its endogenous rank was slam to that of proline accumulated in discs incubated in stress media devoid of glycine betaine (Vílchez et. al., 2018). The worth of glycine betaine in reversing the consequence of osmotic distress on the proline reaction has been long-established in leaf discs encumbered with glycine betaine preceding to their incubation in wilting condition. Glycine betaine might have as well amplified the vacuolar assembly in the roots of salt stressed plants for stockpiling additional Na+ in root cells, which was imperative in the uptake of water for plant confrontation to high salt condition ((Vílchez et. al., 2018, Ashraf and Foolad 2007).

Table 1. Most abundant antioxidants that play essential roles in osmotic regulation under salinity stress.

Antioxidants	Properties	Functions under salinity stress	references
Glutathione (GSH)	Non-enzymatic low molecular weight antioxidant and hydrophilic	Chemically react with free radicals ($O_2^{\cdot-}$, OH.,H_2O_2)and scavenges them	Martinez et al. 2018 (Tomato), Hasanuzzaman et al. 2018 (Brassica), Gupta et al. 2018 (highe plants), Broadbent et al. 1995 (Tobacco), Ruiz-Lozano et al. 2018(Rice), Anderson et al. 2004(spurge), Sofo et al. 2015, Nahar et al. 2015 (Mungbean), Das et al. 2014
Ascorbate (AsA)	Non-enzymatic low molecular weight antioxidant and hydrophilic	Chemically react with free radicals ($O_2^{\cdot-}$,H_2O_2)and scavenges them	Golkar et al. 2018 (safflower), Liang et al. 2018 (Kiwifruit), Sofo et al. 2015, Nahar et al. 2015 (Mungbean), Taïbi et al. 2016(Common bean), Jiang et al. 2017(Maize), Alves et al. 2017(Chick pea), Choudhury et al. 2017, Gill et al. 2010, Gupta et al. 2018 (highe plants)
Polyphenols	Diverse secondary metabolites and non-enzymatic low molecular weight antioxidant and hydrophilic	Directly scavenge molecular species of active O_2	Golkar et al. 2018 (safflower), Golkar et al. 2018 (safflower), Gul et al. 2018 (Maize), Ashraf et al. 2018 (Maize), Liang et al. 2018 (Kiwifruit), Gupta et al. 2018 (highe plants), Nikalje et al. 2018 (Halophyte), Das et al. 2014
Flavonoids	Non-enzymatic low molecular weight antioxidant and hydrophilic	Scavenger of H_2O_2	Ashraf et al. 2018 (Maize), Taïbi et al. 2016(Common bean), Gill et al. 2010, Gul et al. 2018 (Maize), Liang et al. 2018 (Kiwifruit), Gupta et al. Nikalje et al. 2018 (Halophyte)2018 (highe plants), Baskar et al. 2018 (highe plants), Das et al. 2014
Sugar alcohol (eg. Mannitol)	low molecular weight non-enzymatic antioxidant and hydrophilic	Functions as osmoprotectants	Gill et al. 2010, Golkar et al. 2018 (safflower), Gupta et al. 2018 (highe plants), Nikalje et al. 2018 (Halophyte), Das et al. 2014
Tocopherols (vitamin E)	low molecular weight non-enzymatic antioxidant and hydrophobic	Chemically react with free radicals ($O_2^{\cdot-}$, $1O_2$,OH.,H_2O_2)and also scavenges them	Gupta et al. 2018 (highe plants), Kim et al. 2018, Das et al. 2014
Carotenoids	Hydrophobic and non-enzymatic low molecular weight antioxidant	Detoxification of various ROS	Gul et al. 2018 (Maize), Gupta et al. 2018 (highe plants), Nikalje et al. 2018 (Halophyte), Das et al. 2014
Proline	Proline (symbol Pro or P) is a proteinogenic amino acid, organic osmolytes	Acts as an osmoprotectants as able to scavenge ROs	Golkar et al. 2018 (safflower), Vílchez et al. 2018(Pepper), Maghsoudi et al. 2018(Wheat), Gill et al. 2010 ,Hellmann et al. 2000 (Arabidopsis), Wang et al. 2009(alfalfa), Qureshi et al. 2015(Eucalyptus)
Glycine betain	Organic osmolytes	Acts as an osmoprotectants	Vílchez et al. 2018(Pepper), Qureshi et al. 2015(Eucalyptus), Joseph et al. 2017, Volkmar et al. 1998 (Barley and Maize), Chołuj et al. 2008 (Sugar beet)
Superoxide dismutase (SOD)	Metalloenzyme and low molecular weight antioxidant	Catalyzes the dismutation of O_2.- to O_2 and H_2O_2	Liang et al. 2018 (Kiwifruit), Ashraf et al. 2018 (Maize), Golkar et al. 2018 (safflower), Jiang et al. 2017(Maize), Alves et al. 2017(Chick pea), Choudhury et al. 2017, Gill et al. 2010
Catalase (CAT)	low molecular weight enzymatic antioxidant	Catalyzes the dismutation of two molecules of H_2O_2 into H_2O and O_2	Ashraf et al. 2018 (Maize), Liang et al. 2018 (Kiwifruit), Golkar et al. 2018 (safflower), Sofo et al. 2015, Nahar et al. 2015(Mungbean), Taïbi et al. 2016(Common bean), Zhao et al. 2017(Arabidopsis), Jiang et al. 2017(Maize), Alves et al. 2017(Chick pea), Choudhury et al. 2017, Wang et al. 2009(alfalfa), Gill et al. 2010,
Peroxidasa (POD)	Heme containing protein and enzymatic antioxidant	Oxidizes aromatic electron donor such as guaicol and pyragallol at the expense of H_2O_2	Sofo et al. 2015, Liang et al. 2018 (Kiwifruit), Nahar et al. 2015 (Mungbean), Taïbi et al. 2016(Common bean), Jiang et al. Golkar et al. 2018 (safflower), 2017(Maize), Alves et al. 2017(Chick pea), Ashraf et. al. 2018 (Maize), Choudhury et al. 2017, Wang et al. 2009(alfalfa), Gill et al. 2010, Gul et al. 2018 (Maize)
Ascorbate peroxidase (APX)	low molecular weight enzymatic antioxidant	Reduces H_2O_2 to H_2O by using two molecules of AsA and generates monodehydroascorbate (MDHA)	Liang et al. 2018 (Kiwifruit), Ashraf et al. 2018 (Maize), Sofo et al. 2015, Nahar et al. 2015(Mungbean), Taïbi et al. 2016(Common bean), Jiang et al. and Golkar et al. 2018 (safflower), 2017(Maize), Alves et al. 2017(Chick pea), Choudhury et al. 2017, Wang et al. 2009(alfalfa), Gill et al. 2010
Glutathione peroxidase (GPX)	enzymatic antioxidant	Reduces H_2O_2 to H_2O and also organic peroxides	Anderson et al. 2004(spurge), Bela et al. 2015(Arabidopsis), Diao et al. 2014(Rice), Gao et al. 2014(Arabidopsis), Sofo et al. 2015, Nahar et al. 2015(Mungbean), Taïbi et al. 2016(Common bean), Wang et al. 2009(alfalfa), Gill et al. 2010
Glutathione reductase (GR)	NADP(H) dependent enzymatic antioxidant	Reduces GSSG to GSH	Anderson et al. 2004(spurge), Sofo et al. 2015, Nahar et al. 2015(Mungbean), Taïbi et al. 2016(Common bean),

CONCLUSION

Environmental stresses menace plant development, growth also yield and these intimidations are key apprehensions of the human internationally. By means of expansion in population, additional food production is obligatory to congregate global supplies excluding abiotic and biotic stresses lock up its yield. But, amongst all stresses, salinity is the chief distressing since it is prevalent in both arable as well as non-arable lands. The consequences of extreme salts have been pragmatic to have a catastrophic consequence ahead approximately all plants. Therefore, it is decisive to comprehend the cellular mechanisms that take place in plants in saline environment in the trust of ruling an integrated explanation to contest such tribulations. Biotechnology holds pledge for both aspects:
(1) through the most recent tools and techniques, comprehensive studies can be approved away to comprehend the processes inside the cell in different circumstances; in addition to (2) the included prospective of biotechnology can be engaged to contest such harms through changing the hereditary stuffing or by appearance patterns or by optimizing the biochemical with molecular pathways in lots of ways.

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