THINK INDIA Journal

ISSN:0971-1260
Vol-22-Issue-16-August-2019

Functions of Osmolytes In Heavy Metal Stress Amelioration

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Abstract

Global industrialization to make end meets of the booming population comes at the expense of various exposure to environmental contaminants such as heavy metals, which affect the quality of soil and water. On the other hand, heavy metals enter into our food chain which becomes carcinogenic and exhibit lethal effects on human health. The industrial revolution to bring about luxuries and modernized living to the growing population, harness toxic and hazardous chemicals which disturb the ecological balance of the environment. To combat the heavy metal stress, certain defensive strategies like level of osmolytes boost up in the plants, which contribute in the quenching of free radicals.

Introduction

Heavy metals are one among thesechemicals wastes which become entered in the environment and eventually effect human andplant health as well as the aquatic ecosystems [1].Even though heavy metals are generally present in the Earth's crust, exposure toenvironment are common due to anthropogenic sources (mining, agricultural uses andsmelting). Various application and usage of heavy metals in medical, domestic, agriculture,technological and industrial field are entailed to wide exposure to environment [2]. Though some heavy metals such as Co, Mn, Fe, V, Mo, Zn, Cu, Sr, are found insmall amount but a slight increase in their concentration can be toxic and hazardous to humans,plants and animals. Therefore, these are considered as major pollutantsto plants especially to agricultural soil because of the uptake of heavy metal by the plants grown from heavy metal polluted soil [3].

Numerous industries, medical, agricultural and other technological applications contribute metals to wide distribution in the environment. Its toxicity levels depend mostly on several factors such as exposure, chemical species, gender, genetics and nutritional status. They can cause environmental impairment even with an insignificant level of exposure. Plants upon continuous exposure to heavy metal damage cellular activities which lead to oxidative stress [4]. The advancement of industrial revolution has led to the increase of anthropogenic activities. Thus, heavy metals get more accumulated in soil. Heavy metals are very toxic and once they get accumulated to soil, they persist as they cannot be biodegraded which leads to environmental pollutions i.e. water, soil and air pollutions. The effects of various heavy metals have been

ISSN:0971-1260
Vol-22-Issue-16-August-2019

confirmed due to their hazardous effect to environment and prevailingnumerous health issues related to it [5].

Heavy metal toxicity:

The toxicity of heavy metals in plants is greatly contributed by the increase of reactive oxygen species which eventually leads to oxidative stress. As by product of various metabolic pathways plants continuously synthesize reactive oxygen species (ROS) [6]. ROS play important role in tracheary formation, protection against harmful pathogens and several development processes. Generation of ROS should be within plant compatible limits because excess production of ROS cause oxidative impairment to plants such as oxidation of lipids and proteins, degeneration of chlorophyll content and nucleic acid damage. However, ROS generation drastically increases when plants are exposed to various biotic and abiotic stresses. Heavy metals, such as Cu (copper), Ni (nickel), Zn (zinc), Fe (iron), Mo (Molybdenum) and Mn (Manganese) generally depending on their concentration, can be micronutrients and act as cofactor which are crucial for certain enzyme activities and other essential role beneficial to plants [7].

Plants when exposed to higher concentration of heavy metal alter various metabolic activities of plants. Initially when plants are exposed to metal enriched soil, effects on photosynthesis were experienced. Heavy metal noxiousness is stated to disrupt the plasma membrane and cell wall in plants [8]. Lipid membrane conformation gets altered upon contact with heavy metals which controls function and structure of cell membrane and various other cellular processes. Reports suggested that, aluminium leads to lipid peroxidation upon excess free radical production. Increase in lipid peroxidation successively changes the functioning of ATPase bound membrane. Thus, the adverse effect of heavy metal includes inhibiting physiologically active enzymes, mineral metabolism damage and inactivation of photosystem [9].

Role of Osmolytes in Stress Amelioration:

Osmolytes are small molecules which enhances the stability of protein folding, therefore called as chemical chaperones. Osmolytes plays a significant role in amelioration when plants are under stress. It counteracts the activity of various types of stress such as osmotic stress, heavy metal stress and salinity stress [10]. Plants accumulate a range of metabolites mostly in amino acid, on exposing to stressful conditions. Proline, an amino acid acts as an exceptional osmolyte and have three most important roles under stress, they are, metal chelating agent, antioxidativedefence and signalling molecule. Literature assessment specifies that stressful environment eventually leads to prolineoverproduction which enhanced stress tolerance and maintaining homeostasis or cell turgor thus preventing electrolyte leakage by stabilizing membranes and reduces the level of ROS concentration, and prevent from oxidative burst of plants [11]. Osmolyte protects the organism which is under stress, such as high osmotic pressure, extreme temperature, salinity stress, heavy metal stress, UV irradiation, oxidative stress and high light [12]. Osmolytes are readily soluble in water and they have very low molecular mass which

ISSN:0971-1260
Vol-22-Issue-16-August-2019

consist of both electrolytes and non-electrolytes. Osmolyte are composing of organic compounds which are divided into three classes:

- Carbohydrates which includes sorbitol, sucrose and glycerol.
- Amino acids which includes alanine, proline and glycine.
- Methylamines which includes trimethylamine N-oxide (TMAO) and betanine [13].

Proline is compound which isproteinogenic in nature and is required for primary metabolism. Proline accumulation increases upon exposure to biotic and abiotic stress such as the adverse environmental conditions i,e,drought, salinity stress, high light, UV-irradiation, heavy metal stress, oxidative stress [14]. Biotic stress response was first demonstrated in bacteria where it shows its osmoprotective function, which indicates that proline has protective function to plants under stress. However, increase in proline accumulation is not always correlating with abiotic stress, as in *Arabidopsis thaliana* increase in the proline level is due to salt and drought hypersensitive, likewise proline content is high in rice varieties which are drought tolerant but as in Barley salt tolerance is not correlated with high level of proline [15].

However, several reports have shown that high proline accumulation is beneficial to plants with unfavourable conditions to combat the stress [16]. Common heavy metals like Cu, Pb, Cd, Zn and Ni when present in excess becomes a threat to environment especially to plants and excessive heavy metals absorptions trigger stress resulting in serious structural disturbance and physiologic disturbance. Plants when exposed to heavy metals stress plant tends to accumulate more proline. Proline can be a heavy metal chelator, besides osmoprotectant and ROS quencher which alleviate heavy metal stress [17].

Conclusion

The advancement in industrialization and use of modern technologies increased the release of numerous heavy metals into the environment. Heavy metals are a concern to plants even when they are present in less concentration. Since they are non-biodegradable, they remain concentrated in the soil and eventually get accumulated by plants. When plants are grown in heavy metal contaminated soil, they alter the metabolism of the plants and increase ROS generation. Upto certain level ROS are necessary for the biosynthesis of plants but when the plants are under stress, they cause cell injury, oxidative stress and lipid peroxidation and ROS level increase tremendously. Plants have defensive mechanism like osmolyteswhich can scavenge the toxicity of heavy metals. But when heavy metals are in high concentration, exogenous application of scavengers proves to be more effective. Proline, an amino acid is an osmolyte can ameliorate toxicity of heavy metal in plants and make them stress tolerant. Proline being an osmolyte, it enhances the growth and productivity of the plant as well the enzyme activity and photosynthetic content.

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