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Catastrophic Effect Of Fluoride In Plants: A Mini review

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Abstract

Fluoride is the most phytotoxic of the common air pollutants. Fluoride toxicity adversely effects on physiological and biochemical parameters either on agricultural crops, trees, animals or human consumption due to the excess intake of fluoride through drinking water. Fluoride pollution which is now recognized as a global problem shows significant interactions on the metabolic sequence of reactions which is associated with protein synthesis, carbohydrate metabolism and photosynthesis which rarely gives visible symptoms but substantially impairs with growth and yield parameters.Thus, considered as serious contaminant even when present at low levels because it persist for a long time in air, soil, and water and exert negative effects at all levels of an ecosystem. In this paper, consequences of fluoride toxicity on different physiological and biochemical parameters on crop plant have been discussed.

key words*:*Fluoride, Plant, Pollution, Toxicity.

Introduction

Fluoride (F) is one of the strong electronegative element present in the environment, occurs in soil, air, water and the vegetation. F found in ground water has been occurring from the breakdown of rocks, soils; weathering and deposition of atmospheric volcanic particles exist as pollutant. Fluoride pollution has drawn much attention worldwide due to its high concentration in certain soils that leads to toxic effects on the plants (Baunthiyal *et al*. 2014) and thereby F prolged persistence cause serious toxic effects in plants. Toxicity was seen in higher concentrations of NaF solution *i.e.* 100-200 ppm dose. Lethal effect was seen above 200 ppm *i.e.* 500 ppm dose (Kumar *et al*. 2013).

From the soil, F is absorbed by plant roots and then transported via xylem to the transpiratory organs, mainly the leaves, where it can accumulate with adverse effects (Kamaluddin and Zwiazek 2003). F affects a wide range of physiological processes including germination, growth, mineral nutrition, photosynthesis, respiration, carbohydrate metabolism, protein synthesis and lipid metabolism.Changes in enzyme activity and intermediary metabolism caused by chronic fluoride exposure may lead to altered growth, development, and reproduction of the organism. This review provides an overview of information on the cellular and molecular aspects of the interactions between F and plant cells resulting in alteration of various morpho- physiological and biochemical processes.

Fluoride uptake and accumulation

Fluoride enters into plants mainly through two pathways, due to aerial deposition of gaseous F through stomatal diffusion. Through the leaf

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stomata, F permeates the cell walls and migrates towards the margins and tips that are the sites of greatest evaporation (Kamaluddin and Zwiazek 2003). F concentrates in the margins and tip, so these areas generally are the first to show visible injury. Another route is from the soil and water into the plant roots through a passive diffusion process. Subsequently F is transported via xylem through the apoplastic and symplastic pathways in a unidirectional distal movement into the shoots. Fluoride toxicity is a pH-related phenomenon, toxic action starts by damage to the transport channels associated with the cytoplasmic membrane (Saxena and Rani 2012).

Role of fluoride on growth and development

Fluoride causes adverse effects on plant growth and yield. The initial and visible symptoms of F injury to plants are the genesis of necrosis at the tips and margins of the leaves (Mohan *et al*.2007).The F treated plants exhibited a marked reduction in growth parameters i.e. seedling germination percentage, length of root, length of shoot, plant height, number of leaves, size of leaf, number of flowers per plant, fruit-set percentage, and seed-set percentage as compared to control plants (Singh *et al*. 2013).

Failure of the F treated seeds at high concentrations of the applied F that may be consequence of retarded water uptake, inhibited cell divisions, and enlargements in the embryo and an overall decrease in metabolic activity. The blockage of any one of the phases leading to germination may, and very likely ill, completely inhibit the process of germination. The radical and plumule lengths of the treated seedlings of the test plants were considerably reduced at all levels of the applied inhibitors (Gadi*et al*. 2012).

Effect of fluoride on photosynthetic activity

The chlorophylls are primarily involved in harvesting the solar energy and converting it into chemical energy and play a key role in light reaction of photosynthesis; its concentration has direct effect on photosynthetic efficiency of plant. The chlorophyll content in leaves decrease in the case of F treated plants. Decreased chlorophyll content and chlorophyllase activity in plants due to the effect of F, arsenic and heavy metals have been reported by Bhargava and Bhardwaj (2010).The decrease in chlorophyll content may be caused by the breakdown of chlorophyll due to F stress or inhibition of chlorophyll biosynthesis by inhibition of incorporation of aminolevulinic acid.

The F ion also interferes with the biological activity of Mg^{+2}. Total chlorophyll level linearly decreased with increasing F level. This is probably due to higher accumulation of F in leaves and subsequently it can bind readily with Mg^{2+}, forming an MgF^{+} complex (Das *et al*. 2015). This kind of complexation may destroy the photosynthetic pigments, particularly the chlorophylls, thereby significantly decreasing the concentration of pigments. F concentration decline in photosynthetic CO_2 assimilation correlated with loss of stomatal conductance (Oliva and Figueiredo 2005).

Under stress condition plants membranes are subjected to changes such as increase in permeability and loss of integrity. The chlorophyll stability index (CSI) is an indicator of the stress tolerance capacity of plants. Higher CSI indicates the level of polyunsaturated lipids stabilizes chloroplast membrane and increases adaptive responses to tolerance under stress conditions (Gadi*et al*. 2012). CSI percentage decreased significantly by increasing concentration of F. Decrease in pigments content in plants may be due to reduction of membrane integrity of chloroplast lead to reduction in CSI.

Role of fluoride on carbohydrate metabolism

Fluoride increased the total soluble sugar content with the higher concentration. F stress decreased the water potential of the plants by inhibiting root water transport (Kamaluddin and Zwiazek 2003). The increased sugars may act as osmolytes which increase the water potential of seedlings for survival unde water deficit-stress and protect the membrane from damage, as reported earlier in *Trifoliumrepens* (Lee *et al*. 2008). Asthir and Tak (2017) found that in the presence of F reduced the amountof wheat grain starch, where as contents of total free sugars, particularly sucrose, andsoluble protein increased. It was found that F inhibited the activities of invertase and amylase. F often inhibits enzymes that require such cofactors as Ca^{2+}, Mg^{2+}, and Mn^{2+} ions. Thus the inhibition of amylase and invertase activities can be attributed, in part, to removal of the cofactor Ca^{2+}, Mg^{2+} and Mn^{2+} ions (Wilde and Yu 1998). F competition with Mg^{+2} resulted in a slow decrease of enzyme activity and subsequently, in a complete loss of enzyme activity. Inhibition of phosphoglucomutase, another enzyme participating in sucrose biosynthesis, in higher plants could account for the inhibition of sucrose synthesis in F-fumigated plants.

It has been suggested that changes in photo assimilated partitioning between sucrose and starch synthesis observed in many organs of different species are related to PPi accumulation. Pyrophosphate concentration, among other factors, is dependent upon the activities of the enzymes ADPG-pyrosphosphorylase and alkaline pyrophosphatase. In spite of being sensitive to F, the ADPG-pyrophosphorylase is completely inhibited by concentrations of PPi as low as 1mM. The alkaline pyrophosphatase, on the other hand, is inhibited by F (Asthir*et al*. 1998), leading to PPi accumulation and reduction in starch biosynthesis.

Fluoride generate oxidative stress

Oxidative stress is a condition that indicates the imbalance between the pro-oxidants and antioxidants leading to the chemical injury to lipids, proteins and DNA. F compound cause oxidative damage to developmental processes, plants either directly or indirectly by triggering an increased level of production of reactive oxygen Species (ROS). These ROS include super oxide radical, hydroxyl radical and hydrogen peroxide (H_2O_2) and products during membrane linked electron transport activities as well as by a number of metabolic pathways and in turn cause damage to the biomolecules such as membrane lipids proteins lipids chloroplast pigments, enzymes, nucleic acids (Kumar *et al*. 2010).

Superoxide free radicals have the potential to cause adverse effects on biomolecules. They can damage membrane lipids through lipid peroxidation, and cause enzyme inactivation and DNA-strand breakage. Plants have antioxidant defense mechanisms comprising the enzymes catalase, peroxidases, superoxide dismutase, and non enzymatic constituents. Lipid peroxidation levels were increased with increasing F concentration and time of exposure (Tak and Asthir 2017). Antioxidant treatment consistently protects cells from the lipid peroxidation caused by F exposure, suggesting that oxidative damage is the major mode of action of F. Ascorbic peroxidase along with catalase and super oxide dismutases are considered as key enzymes within the antioxidative defense mechanism, which directly determine the cellular concentration of oxide and hydroxyl (Asada 1992). Glutathione levels are also altered by F, often resulting in the excessive production of ROS at the mitochondrial level, leading to the damage of cellular components. Catalase can also use H_2O_2 in order to detoxify some toxic substances via a peroxidase reaction (Mayo *et al*. 2003). Possibly, the hydroxyl ions attached to iron atoms in catalase compounds are replaced by low molecular weight anions in sufficient concentration leading to this inhibition.Peroxidase is ubiquitous antioxidant enzymes that participate in cellular redox homeostasis and have also been shown to increase under several abiotic stresses (Barranco- Medina *et al*. 2007). Peroxidases utilizing guajacol as electron donor in vitro are guiacol peroxidases and participate in developmental processes, lignifications ethylene biosynthesis, defense, wound healing etc.

The increased activity of super oxide dismutase may be partly due to an increased metabolic activity or an increased rate super oxide dismutase biosynthesis under the influence of F exposure. This enhanced activity may be an adaptive reaction to changes in oxidative stress which can be considered as a positive feedback mechanism (Chakrabarti and Patra 2013).

Organic osmolytes including proline, glycine betaine, aspartic acid, mannitol, pinitol, myoinositol and sugars are accumulated in plant cells under adverse environment (Datta *et al*. 2012). Proline accumulation in response to stress is widely reported, and may play a role in stress adaptation within the cell, which is of great interest to those studying stresses in plants (Gibon *et al*2000). The rapid accumulation of amino acids during salinity stress suggests that these compounds may be acting as sinks for excess N in relation to the decreased growth occurring during the imposed stress. Amino acids also play a role in osmotic adjustment, and serving as available sources of carbon and nitrogen. Several explanations for the accumulation of free amino acids and amides under stress have been suggested. These include stimulation *de novo* synthesis, inhibition degradation of amino acids, impairing protein synthesis, and/or enhanced protein degradation (Gibon *et al*. 2000).

Conclusion

Overall the review concludes that F toxicity is a worldwide problem, which adversely affects plants. Fluoride in air and soil adversely affects the crop growth and yield and has serious repercussion on world agriculture The studies on the consequences of fluoride toxicity stress on crop plants needs more attention to understand the physiological, biochemical and molecular basis of fluoride tolerance of crops. Genetic malformation can produce any type of physiological or biochemical change in a plant body, imposing harmful effect on plant species and the agricultural system Therefore, further research at molecular levelcan only help to understanding fluoride toxicity stress in plants and development tolerant genotypes for sustainable crop production under abiotic stresses like fluoride toxicity.

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