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EFFECTS OF NICKEL AND ZINC ON BIOCHEMICAL PARAMETERS IN PLANTS- A REVIEW

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Abstract: The focus of the review is on the specific aspects of Ni and Zn effects on growth morphology, Biochemical activity/responses, mineral nutrition and enzyme activity of plants. The quantity of Ni required for normal growth and development of plant is very low. Ni has been identified as a component of various enzymes in plants, various other biochemical, physiological and growth responses. The concentrations of Ni and Zn in the environment are currently increasing due mainly of human activities. Zn and Ni are essential elements for several biochemical processes in plants. At high concentration in soil, can cause severe damage to physiological and biochemical activities of plants. The higher concentration of Ni is associated with soils, plants chlorosis and inhibits, root and shoot growth. Excess of Ni inhibits a large number of enzyme and including photosynthesis; pigments synthesis.
Keywords: Biochemical constituents, Heavy Metal, Nickel, Zinc.
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INTRODUCTION

Heavy metal contamination in the environment is a worldwide problem, which is threatening to the plants, animals and human beings. Some of the heavy metals including nickel and zinc occur naturally in soils as trace elements. The biota-require some of these elements as essential micronutrients. The term heavy metal refers to any metallic element that has a relatively high density (above 5 g/cm^3) (Lenntech, 2004). These essential heavy metals at their higher concentrations are toxic in living organisms. Their release into the environment in biologically available forms, through various sources, may damage or alter both natural and man-made ecosystems (Singh and Pandey, 2011). Plants, like all other organisms, in order to maintain the concentration of essential heavy metals within the physiological limits and to minimize the detrimental effects of nonessential metals, have evolved a complex network of homeostatic mechanisms. It serves to control the uptake, accumulation, trafficking and detoxification of metals. However, some plants can grow on soil contaminated with heavy metals which tolerate not only the higher levels of metals, but even hyper-accumulate them (Clemens, 2001). This trait can be used in the process of phytoremediation to clean contaminated soil and water (Baker and Whiting, 2002).

SOURCES OF NICKEL AND ZINC IN PLANTS

Sources of Ni and Zn in soils mainly include natural occurrence derived from parent materials and human activities. Anthropogenic inputs are associated with industrialization and agricultural activities desposition such as atmospheric desposition, waste disposal, waste incineration, urban effluent, traffic emission, fertilizer application and long term application of waste-water in agricultural land (Koch and Rotard, 2001). Apart from the sources of heavy metals, the physico-chemical properties of soil also affect the concentration of heavy metals in soil, and their availability to plant roots. Organic matter content and pH are the most important parameters controlling the accumulation and the availability of heavy metals in soil environment (Nyamangara and Mzezewa, 1999). The irrigational use of industrial effluent, which carries heavy metals including Ni and Zn pose adverse effects on plant growth (Pandey *et al*., 2008). These heavy metals enter the food web, where they get biomagnified and create possibility to biodiversity loss (Reichman *et al*., 2001). The biochemical effects of metal ions in the cell have been reported by (Naaz and Pandey, 2010; Singh and Pandey, 2011). The accumulation of heavy metals in agricultural soils is of increasing concern due to the food safety issues and potential health risks as well as its detrimental effects on soil ecosystems (McLaughlin *et al.,* 1999).

Metal-induced changes in development are the result of either a direct or indirect impairment of metabolism (Woolhouse, 1983). Transport processes have been recognized as a central mechanism of metal detoxification and tolerance (Hall, 2002; Hall and Williams, 2003). Nickel pollution has become a serious global problem (Viet *et al.,* 2010). Nickel is established as an essential trace metal for at least several animal species, micro-organisms and plants (Gerendas *et al.,* 1999). It is the 24th most aboundment element in the earth's crust. The compound of Ni has many industrial and commercial uses, and they are widely distributed in the environment, being released from both natural sources and anthropogenic activities, with input from both stationary and metabolic sources.

Nickel is generally distributed uniformly throughout the soil profile, but typically it accumulates at the surface from deposition by industrial and anthropogenic activities. High content of Ni cause problems in land near towns, in industrial areas or even in agricultural land receiving wastes such as sewage sludge etc. Its content in soil varies in a wide range from 3 to 1000 mg/kg (Alloway, 1995). Nickel is vital for the function of many organisms; on the other hand its higher concentration in the environment may be toxic for certain organisms (Baccouch *et al*., 2001). Low concentration of Ni promotes plant growth and is probably involved in different physiological processes (Brown *et al*., 1987). This element is a component of the enzyme urease and is essential for its function (Gerendas *et al.,* 1999). Nickel is essential for plant species that use ureides in their metabolism (Marschner, 1986). Plants which are Ni-deficient, accumulate urea in their leaves and show leaf tip necrosis (Taiz and Zeiger, 1998). Nitrogen- fixing microorganisms require Ni for hydrogen uptake and hydrogenase and nickel-deficiency may, therefore, cause nitrogen-deficiency in the plant (Gerendas *et al.,* 1999).

PLANT RESPONSES TO NICKEL

A lower concentration of Ni has been reported to play a variety of roles in promoting plant growth and metabolism (Brown *et al.,* 1987; Pandey *et al.,* 2009). However, it shows harmful effects at higher concentrations (Eskew *et al.,* 1984; Hasinur *et al.,* 2005). Excessive Ni in growth medium inhibits seed germination, plant growth, induces chlorophyll degradation, and interfere photo-system activity (Ahmad *et al*., 2009; Ali *et al.,* 2009). At the molecular level, Ni also induce the generation of reactive oxygen species (ROS), which cause oxidative damage of lipids, proteins, and nucleic acids in plant cells (Gajewska *et al.,* 2006; Gajewska and Sklodowska, 2007). However, plants are able to cope with the effects of over production of partly reduced ROS during oxidative stress by activating numerous protective mechanisms. Excess concentration of Ni causes chlorosis and necrosis, resulting from disturbed iron uptake and metabolism (Croock, 1958). Elevated concentrations of nickel can inhibit cell division at root meristems in non-tolerant plants (Robertson, 1985). High concentrations of Ni in plants cause membrane destabilization due to increase in production of highly toxic oxygen species, namely superoxide radical (O^-), hydrogen peroxide (H_2O_2), and hydroxyl radicals (OH^-.). To ensure the sequence of metabolic reactions, plants develop an enzymatic protective mechanism that is comprised of antioxidant enzymes (peroxidiase, catalase, superoxide dismutase, ascorbate peroxidase, glutathione reductase and osmolytes (proline and glycine). Production of proline in stressed plants is associated with detoxification of heavy metals, reduction of damage to membranes and proteins. It also provides reducing equivalents that support mitochondrial oxidative phosphorylation and the generation of ATP for recovery from stress-induced damage (Schat *et al.,* 1997; Mehta and Gaur, 1999; Siripornadulsil *et al.,* 2002; Sharma, 2006). This is done by replenishing the cellular levels of natural antioxidants such as the reduced form of glutathione, or by turning on and off the expression of multiple genes encoding various antioxidant proteins, such as thioredoxin and related molecules (Mittler, 2002). The Ni-induced growth inhibition has been ascribed to down regulation of protein synthesis and the activities of some of the enzymes responsible for the metabolism of food reserve but the binding of metals to phytochelatins has, as yet, only been demonstrated for metals (Kahle, 1993; Grill *et al.,* 1988).

PLANT RESPONSES TO ZINC

Zinc is an essential element for the normal growth and metabolism of plants, plays very important role in enzyme activation and it is involved in the biosynthesis of some enzymes and growth hormones (Daviscarter and Shuman, 1993). Complete exclusion of Zn is not possible due to its dual role, an essential micronutrient on the one hand and a toxic environmental factor on the other (Brune *et al*.,1994). The physiology of Zn toxicity in plants concerned with metal movement from soil to root and metal absorption and translocation to aerial shoots (Marschner, 1986). Plant availability of a metal in the soil depends on soil absorption strength as well as plant factors such as root exudates for metal chelation or reduction. Zinc is also a constituent of metalloenzyme or a cofactor of several enzymes such as anhydrase, dehydrogenase, oxidases and peroxidases, and plays an important role in regulating the nitrogen metabolism, cell multiplication, photosynthesis and auxin synthesis in plants (Sharma, 2006).

Zinc is a co-factor of more than 200 enzymes, such as oxidoreductases, hydrolases, transferases, lyases, isomerases, and ligases. Many of the metalloenzymes are involved in the synthesis of DNA, RNA and protein synthesis and metabolism of plants (Prasad, 2007). Zinc, is a non-redox micronutrient element, which has key structural and catalytic roles in many proteins and enzymes involved in energy metabolism (Sresty and Madhava Rao, 1999; Hall and Williams, 2003). Zinc also increase the biosynthesis of chlorophyll and carotenoids, beneficial for the photosynthetic machinery of the plant system has been reported (Aravind and Prasad, 2004). Zinc deficiency is a major global problem hindering plant cultivation, and this problem is especially exacerbated in alkaline and calcareous soils which are the most common soil types in arid and semi-arid regions of the world (Cakmak, 2000; Hacisalihoglu *et al*., 2004). Low availability of Zn in calcareous soils is one of the widest ranging abiotic stresses in world agriculture. Zinc deficiency is responsible for many severe health complications in human beings including impairments of physical growth, immune system and learning ability, combined with increased risk of infections, DNA damage and cancer development (Hotz and Brown, 2004; Gibson, 2006; Prasad, 2007). Zinc deficiency reduces plant growth and inhibits photosynthesis in a wide variety of plants including maize (Wang and Jin, 2005) and rice (Wenrong *et al*., 2008). It is, one of the major heavy metal that pollute soil, originates from natural pedochemical background, atmospheric transport (Steinnes and Friedland, 2006) as well as old or recent pyrometallurgical slag weathering (Ettler *et al*., 2002). This metal ion is easily assimilated by plants, but it can also prove strongly phytotoxic at its elevated levels in plants (Broadley *et al.,* 2007). Growth inhibition is a general phenomenon associated with Zn toxicity (Marschner, 1995; Hagemeyer, 2004). However, plants exhibit a variety of responses in reaction to stresses generated by Zn or other trace element. These responses imply morphological, biochemical and physiological changes which, taken together, improve the tolerance of the plants to the imposed toxic effects (Hall, 2002). High concentration of Zn in the plant tissue seriously affects activity of several enzymes and other fundamental metabolic processes. An excess of Zn also reduces photosynthetic rate as a part of enzymes concerned in the photosynthesis. Excess Zn is a major problem in the soils contaminated by mining, industrial activities and long use of sewage sludge for agricultural purposes (Luo and Rimmer, 1995; Vaillant et al., 2005). Excess Zn has been reported to have a negative effect on mineral nutrition and enzyme activities related to metabolism of plants (Pandey *et al*., 2011). Zinc toxicity induces chlorosis in young leaves, and this has been suggested to result from a Zn-induced Fe or Mg deficiency, based on the fact that these three metals have similar ion radii (Marschner, 1995). High Zn concentration in root tissues affect the disintegration of cell organelles, disturbance of membranes and condensation of chromatin material and increase in number of nucleoli (Sresty and Madhav Rao, 1999). Which take place during seed germination (Foy *et al*., 1978). Nickel induces phytochelatin production; Phytoremediation is a technology which uses plants to remediate metal contaminated soils. Phytoextraction aims at cleaning up the soil through the uptake of pollutants by the roots (McGrath and Zhao, 2003). The severity of a metal toxicity is reduced by interactive effect of other metal. It is reported that, some heavy metals may reduce the metal uptake in plants via competition, which ameliorates metal toxicity (Noraho and Gaur, 1995). Zinc form metallopolypeptides like phytochelatin and contribute to tolerance mechanisms against metals toxicity (Perl *et al.,* 1993). Zinc catalyzes rapid detoxification of superoxide ions by producing hydrogen peroxide, which can be taken care of by the other enzymatic components of the antioxidant systems such as catalase and peroxidase (Cakmark, 2002). The amelioration of toxicity of metal by antagonistic effect of other metal at different concentrations could be a tool for understanding the bio-remedial approaches. It is necessary then to evaluate the relationship among these parameters and heavy metals availability to plants.

GROWTH AND CYTOGENETIC EFFECTS OF NICKEL AND ZINC

Heavy metals including Ni and Zn at excess levels in growth medium induce cytogenetic effects in root tip cells of plants (Inceer *et al.,* 2003; Chandra *et al.,* 2005). Chandra *et al.* (2005) reported that, leachates from soil waste of a metal and dye industry induce the possible genotoxic effects in *Allium cepa*. Also, both the metal waste and dye waste leachates contain high concentration of Cr, Ni, Zn and Fe which induce cytogenetic alterations and significant inhibition of mitotic index (MI) and micronuclei (MN) formation. Beltagi (2001) reported that, heavy metals (Cd, Cu, Ni, and Zn) cause biochemical and physiological effects on vegetative and reproductive growth, flowering and total RNA content in seeds, and root nodules in *Vicia faba* plants. The general principles of the mechanisms of mitosis are best and most easily studied in the actively growing regions of plants such as a shoot or root apex. Frequently, such studies involve the use of chemicals which modify the normal course of mitosis (Levan, 1938; Love and Love, 1975). The adverse cytological effects of heavy metals and chemicals (Ene-Obong and Amadi, 1987; Jose *et al.,* 2008), and their protective measures have been studied by several workers (Haroun and Al shehri, 2001; Omari *et al.,* 1996; Qureshi *et al.,* 1988; Mekki, 2008).

Available literature and accessible data put a spot light on the natural occurrence of Nickel and Zinc in soils and shows how their low concentration in plants is important for plant growth, on the other hand their higher concentrations pretense injurious effects on plant and animal health. As by entering in to the food web it may leads to biodiversity loss. slightest information are available regarding metal-tolerant species, interactive effect of metals for amelioration of phytotoxicity and other counteractive measure to detoxifying the metals. Along with this, information on metals toxicity to cytological effects in plant root is available to a limited number. Therefore, more study and work is needed to pull together the information of above mentioned evils for the health of plant from Ni and Zn stresses.

CONCLUSION

Plants grow on Ni and Zn in soils resiltant in reduction in growth due to changes in their physiological and biochemical activities especially true when the Ni and Zn involved does not play any beneficial role towards the growth and development of plants. Therefore, indeed to intensify the research for better understanding of Ni and Zn toxicity in plants. There are two types aspects on the interaction of Ni and Zn in plants, one hand, Ni and Zn show negative effects on plants and other hand, plants have their own resistance mechanisms against toxic effects. Their responses include growth inhibition of plants, wilting and leaf chlorosis and reduction of total plant yield. Our review showed that both growth and photosynthetic pigments are affected by the presence of Ni and Zn. The toxicity of both metals which is cause by their accumulation in soil can be removed by phytoremediation process effectively use for the treatment of ni and Zn in soil. However, many such plants have limited utility for phytoremediation, because of their slow growth, and low biomass

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