frontiers in Environmental Science

MINI REVIEW
published: 21 November 2016
doi: 10.3389/fenvs.2016.00069

Influence of High and Low Levels of Plant-Beneficial Heavy Metal Ions on Plant Growth and Development

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Specialty section:
This article was submitted to Environmental Toxicology, a section of the journal Frontiers in Environmental Science

Received: 30 June 2016
Accepted: 12 October 2016
Published: 21 November 2016

Citation:
Arif N, Yadav V, Singh S, Singh S, Ahmad P, Mishra RK, Sharma S, Tripathi DK, Dubey NK and Chauhan DK (2016) Influence of High and Low Levels of Plant-Beneficial Heavy Metal Ions on Plant Growth and Development. Front. Environ. Sci. 4:69. doi: 10.3389/fenvs.2016.00069

Heavy metals (HMs) exists in the environment in both forms as essential and non-essential. These HM ions enter in soil biota from various sources like natural and anthropogenic. Essential HMs such as cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Zn) plays a beneficial role in plant growth and development. At optimum level these beneficial elements improves the plant's nutritional level and also several mechanisms essential for the normal growth and better yield of plants. The range of their optimality for land plants is varied. Plant uptake heavy metals as a soluble component or solubilized them by root exudates. While their presence in excess become toxic for plants that switches the plant's ability to uptake and accumulate other non-essential elements. The increased amount of HMs within the plant tissue displays direct and indirect toxic impacts. Such direct effects are the generation of oxidative stress which further aggravates inhibition of cytoplasmic enzymes and damage to cell structures. Although, indirect possession is the substitution of essential nutrients at plant's cation exchange sites. These ions readily influence role of various enzymes and proteins, arrest metabolism, and reveal phytotoxicity. On account of recent advancements on beneficial HMs ions Co, Cu, Fe, Mn, Mo, Ni, and Zn in soil-plant system, the present paper: overview the sources of HMs in soils and their uptake and transportation mechanism, here we have discussed the role of metal transporters in transporting the essential metal ions from soil to plants. The role played by Co, Cu, Fe, Mn, Mo, Ni, and Zn at both low and high level on the plant growth and development and the mechanism to alleviate metal toxicity at high level have been also discussed. At the end, on concluding the article we have also discussed the future perspective in respect to beneficial HM ions interaction with plant at both levels.

Keywords: essential heavy metals, environment, tronsporters, uptake, plant, growth

INTRODUCTION

Heavy metal like cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Zn) enters in soil from various sources such as mining, foundries, smelters, combustion, and agriculture (Nagajyoti et al., 2010). Plant genomes encode a number of transporters that are specific in their substrate specificities, expression, and in cellular localization to manage the translocation of these metals into the whole plant (Colangelo and Guerinot, 2006; Hwang et al., 2016). These metals are acting a beneficial role for plant growth, development, and productivity at an optimum concentration in the form of the essential micronutrient (Singh et al., 2016). To grow and complete the life cycle plants use these essential micronutrients (Wuana and Okieimen, 2011). The plant takes these essential heavy metals like iron, zinc, copper, and manganese from the soil due to concentration gradients and selective uptake of these metals (Peralta-Videa et al., 2009). These ions enthusiastically affected the function of many enzymes and cellular metabolism. These metals also play a prominent role in the synthesis of protein, nucleic acids, photosynthetic pigment, and it also take part in the structural and functional integrity of cell membranes (Oves et al., 2016). For instance Copper is an essential heavy metal which actively takes part in the photosynthesis (Gad, 2012). Manganese is an important constituent of various metabolic enzyme like mallic dehydrogenase and oxalosuccinic decarboxylase (Millaleo et al., 2010), Cobalt found in the form of Vitmain B12 (Barker and Pilbeam, 2015), while Fe act as a cofactor in cytochrome (Thomine and Lanquar, 2011). Although the concentration of these heavy metal ions in soils is severely altered by the arbitrary human activities and through the various natural process (Singh et al., 2011). The enhanced concentration of these beneficial ions poses a toxic effect into the plant cells. These effects may be substituted of essential functional groups, cellular damage, generation of reactive oxygen species (ROS), disturbance in the various metabolic reaction by altering the enzymatic activity (Anjum et al., 2015). Regarding the above facts, it is noticeable that only a limited amount of these beneficial heavy metals is essential for the plant growth and metabolic function. Therefore, in the current article we elaborately reviewed various studies regarding heavy metals sources, their uptake mechanism, essential transporters and also discuss about the constructive, and destructive properties of heavy metals in response to their concentration.

SOURCE OF VARIOUS BENEFICIAL HEAVY METAL IONS

There are numerous source of HMs contamination in the surroundings like natural, and anthropogenic including agricultural, industrial, domestic, and atmospheric (Bing et al., 2011). The most imperative natural source of HMs contamination is geological bedrock and rock substratum (Tchounwou et al., 2012). The composition and amount of heavy metal specifically relies on the type and concentration of rocks and as well as on the weathering process (Wuana and Okieimen, 2011). The inorganic and organic fertilizers are the agricultural sources of heavy metal contagion, liming, sewage disposal, irrigation water, and pesticides are the main cause of heavy metal discharge in the soil (Chopra et al., 2009). A case study around peri-urban and urban-industrial clusters in Ghaziabad, India, reveals that waste water irrigation is responsible for the heavy load of heavy metal in agricultural soils, crops, and vegetables (Chabukdhara et al., 2016). Mining refinement such as spoil heaps, tailings, transportation of ores, smelting metal finishing, and recycling of metals are the industrial process that liberates the HMs in the environment (Tchounwou et al., 2012), For instance, Deng et al. (2016) through their study suggested that the atmospheric deposition is the major cause of Pb, Cd, Cu, Cr, and Zn accumulation in plants of peri-urban and smelting contaminated sites in Baoji, China. While the explosion, landfills, and transportation like automobiles, diesel powered vehicles, and aircraft are also the source of heavy metal pollution (Wuana and Okieimen, 2011). Anthropogenic activities like coal mining, waste combustion, and steel processing are the major cause of rising level of zinc (Lottermoser, 2010). The excessive injudicious and unregulated use of Cu fungicides, bactericides and Chromium (Cr) contaminates the environment through the electroplating processes and waste material pesticides to control plant diseases and pest that has resulted in Cu accumulation in surface layer of agricultural soil (Mackie et al., 2012).

UPTAKE AND TRANSLOCATION OF BENEFICIAL HEAVY METAL IONS

Soil is the reservoir of various HMs contaminations and has strong property of cation exchange capacity. Among these HMs some of the metals such as Co, Cu, Cr, Fe, Mg, Mn, Mo, Ni, Se, and Zn are essential element, that are required in very small amounts for optimum plant growth and development (Alloway, 2013). These beneficial HMs plays several biochemical and physiological task in plants and also regarded as significant constituents of various cellular enzymes moreover actively take part in several oxidation-reduction reactions (Emamverdian et al., 2015). For instance, Fe easily reduced and oxidized in various biochemical processes and also an important cofactor of many enzymes which involves in the respiration, photosynthesis, and nitrogen assimilation (Hell and Stephan, 2003). Zn is a vital structural constituent of protein and also acts as a cofactor of several enzymes (McCall et al., 2000). Zn absorption, uptake, and accumulation in plants occurs throught the involvement of Zinc transporters and metal chelatiors into the plant (Gupta et al., 2016). Cu also acts as an essential element for plant growth by participating in many redox-active reactions. Mn plays an important role in detoxification of ROS (Ducic and Polle, 2005). Plant absorb essential and non-essential element from the soil in response to concentration gradient and selective uptake of ions or by diffusion (Peralta-Videa et al., 2009). The absorption level of different element relies upon the different plant species. Root plays a significant role in the active uptake of metal ions. The mechanism is mainly started by the absorption of metal ions in the root tissue, the ions of Co, Cu, Fe, Mn, Mo, Ni, and Zn dissociates from its complex forms at the root surface. The metals are heavily accumulated into the root apoplast (Krzesłowska, 2011). The adsorption of heavy metals on the root surface takes place in cationic form with negative cell wall due to the presence of cellulose, pectins, and glycoproteins that work as specific ion exchangers. The adsorption and translocation of metal ions occurs in xylem and phloem tissue through the root by two ways known as apo-plastic and symplastic (Hossain et al., 2012). The apoplastic transportation occur through the intercellular spaces by the diffusion of metal ions in the root cell through the soil solution, while the symplastic transportation of metal ions takes place through the plasma membrane by the different carrier or transporters (Barberon and Geldner, 2014).

METAL TRANSPORTERS

Beneficial metal nutrient elements like Co, Fe, Mn, Cu, Mo, Ni, and Zn are essential for normal plant growth and development (Loftleidir, 2005). These metal nutrients occur in the soil in limited amount and transported to the plant in a homeostatic way by the metal transporters (Krämer et al., 2007). Several workers disclose the role of transporters in beneficial metal adsorption and translocation in plants (Krämer et al., 2007; Puig et al., 2007). Grotz and Guerinot (2006) reported the uptake of Fe and Zn ion which is mediated by a group of transporters belonging to the ZIP family like ZRT (Zinc regulated transporters) and IRT (Iron regulated transporters) proteins in higher plant. Kim and Guerinot (2007) stated in his article that IRT1 is able to mediate the transfer of multiple metals including Fe, Mn, Zn, and Cd. Hussain et al. (2004) in their article "P-Type ATPase heavy metal transporters with roles in essential zinc homeostasis in *Arabidopsis*" reported the role of HMA2 (Heavy metal ATPase) and HMA4 in essential Zn homeostasis (Table S1). The absorption and translocation of copper occurs in plants by the CTR (Copper transporter) and COPT1 (Copper transport protein; Sancenón et al., 2003). Cu transported in plants by the two types of transporters first one is P-type ATPases belonging to the HMA family and second one is RAN1 (Responsive-to-Antagonist) also known as HMA7 (Sancenón et al., 2003; Table S1). Colangelo and Guerinot (2006) stated in their article that YSL (Yellow strip-like) members have been involved in the transportion of metals such as Fe and Mn ions in rice plants (Table S1). Mizuno et al. (2005) reported the three ZIP/NRAMP (natural resistance-associated macrophage protein) transporter genes from a Ni hyperaccummulator plant *Thalpsi japonicum* and their Ni–transport abilities (Table S1). The obtained result suggested that ZIP/NRAMP transporter contributes in Ni homeostasis in plants (Table S1). TjZNT1 has Zn, Cd and Mn ion transportation ability and TjZNT2 also has Zn and Mn transporting capacity, while TjNRAMP4 could only transport Ni (Table S1).

IMPACT OF BENIFICIAL HEAVY METALS ON PLANTS AT LOW LEVEL

Beneficial HMs like Co, Cu, Fe, Mn, Mo, Ni, and Zn (Blaylock and Huang, 2000) at low level or under an optimum range induces essential biochemical and physiological reactions in plants (Nagajyoti et al., 2010). Cobalt plays an essential role in plant growth development by regulating plant water utilization and reducing transpiration rate (DalCorso et al., 2014). Gad and Hassan (2013) carried out an experiment on tomato plant with Co application at 7.5 ppm, which enhanced the growth, yield, nutrient levels, and chemical constituents of tomato plant with better quality of fruits (**Table 1**; **Figure 1**). Copper being an essential HM, at low amount helps in enhancing the plant photosynthesis (Mahmood and Islam, 2006). It involves in physiological functions and is a crucial cofactor for many metaloprotiens (Yruela, 2005). Copper is a vital element for plant growth and development (**Table 1**; **Figure 1**), also proved as a micronutrient for plants (Kabir et al., 2009) and it plays an imperative function in CO_2 assimilation and ATP synthesis (Pichhode and Nikhil, 2015). Cu at optimum level is valuable element of various proteins such as plastocyanin of photosynthetic system and cytochrome oxidase of respiratory electron transport chain in plants (Demirevska-Kepova et al., 2004). Considering Fe as beneficial HM for plants, it is essential for respiration, photosynthesis, nitrogen fixation (**Table 1**; **Figure 1**), various cellular processes like DNA synthesis and hormone production (Becana et al., 1998; Møller et al., 2007), chloroplast development and chlorophyll biosynthesis (Møller et al., 2007). It is a constituent of heme protein (cytochromes, catalase, peroxidase, and leghemoglobin) and iron sulfur protein (ferredoxin, acontiase, and SOD; Gill, 2014). Low pH level of soil makes the Fe more readily available for the plant root Fe uptake (Marschner, 1995; Asati et al., 2016). Manganese is a vital plant nutrient element; predominantly it plays an imperative role in structuring photosynthetic proteins and enzymes and positively affects the biosynthesis of growth substances (**Table 1**; **Figure 1**) and the gene expression (Frassinetti et al., 2006). It also regulates the metabolism of carbohydrates and lipids, relocation of trace ions, and other HMs in soils (Marschner and Rengel, 2007). Shenker et al. (2004) propounded about the Mn nutritious possessions on tomato (*Lycopersicon esculentum*) and role of Mn on enhancing growth, chlorophyll content and SOD (superoxide dismutase) activity of tomato plant at 7.6 and 8.6 mg kg^{-1} Mn concentration (**Table 1**; **Figure 1**). In significant perspective of Mo, it is a constituent of more than 60 metalloenzymes and proteins (Kaiser et al., 2005; Mendel and Schwarz, 2011). Plant requires Mo in the range of 0.1–1.0 ppm (McGrath et al., 2010), enhances the total chlorophyll concentration in plants (Datta et al., 2011). Nickel is another beneficial element for plants. It required by the plant in a very little amount for normal plant growth and functioning (Izosimova, 2005). Zinc is a crucial element that influences a number of metabolic processes of plants, it also plays a significant role in producing chlorophyll thus it is vital for normal plant growth (**Table 1**; **Figure 1**). Even so beneficial HM ions like, Co, Cu, Fe, Mn, Mo, Ni, and Zn also regulate plant's ROS scavenging system involving enzymatic and non-enzymatic antioxidants mechanisms (Gill and Tuteja, 2010).

IMPACT OF BENIFICIAL HEAVY METALS ON PLANTS AT HIGH LEVEL

Plants are frequently sensitive both to the low and high accessibility of some heavy metal ions as essential micronutrient. Beneficial heavy metals at high level could upsets the soil environment that consecutively adversely influences soil fertility, plant growth and development (Reeves and Baker, 2000). The

TABLE 1 | Effect of beneficial heavy metal on different plants at low level.

Metals	Plants	Metal concentration at low level	Impacts on plant	References
Co	Cowpea (*Vigna unguiculata*)	8 ppm	Enhanced plant growth and yield. induced nodulation. maintained the level of mineral composition and chemical constituent.	Gad et al., 2013
Co	Maize (*Zea mays* L.)	50 mg Co kg^{-1}	Increased seedling growth, photosynthetic pigments viz., chlorophyll a, chlorophyll b, and total chlorophyll contents. Elevatad the level of total sugars, starch, amino acids, protein content, and mineral content.	Jaleel et al., 2008
Cu	Wheat (*Triticum aestivum* cv. Hasaawi)	2 mM	Promoted growth and increased biochemical parameters. increased the biosynthesis of free amino acid, proline, and activity of antioxidant enzymes.	Azooz et al., 2012
Mn	Tomato (*Lycopersicon esculentum* Mill.) seedling	7.6–8.6 mg kg^{-1}	Middle leaves of tomato seedling showed optimal plant growth. Normal chlorophyll content observed. Elevated the level of Fe in shoots. Reduced cytosolic CuZn-SOD and chloroplastic CuZn-SOD activities.	Shenker et al., 2004
Mo	*Glycyrrhiza uralensis*	0.52 mg·L^{-1} and 5.2 mg·L^{-1}	Promoted the Secondary metabolic process of glycyrrhizic acid content and its biosynthetic precursor squalene. Also promoted the expression of the key synthase b-AS gene.	Wang et al., 2013
Mo	Bengal gram (*Cicer arietinum*)	1.5–4.5 ppm	Increased root and shoot length. Significantly increased fresh weight and dry weight of seedling. Increase germination. Increased ascorbic acid concentration total soluble sugar and chlorophyll content.	Datta et al., 2011
Zn	*Mentha piperita*	1, 1.5, 2, 2.5, 3, and 3.5 ppm	Recorded increased number of leaves/hactor. Elevated level of essential oil. enhanced the growth and and yield.	Akhtar et al., 2009
Zn	Groundnut (*Arachis hypogaea*) and wheat (*Triticum aestivum*)	2.5, 5.0, 7.5 kg/ha	Increased kernel yield, improved the kernel weight, oil, and protien content. incresed biomass production.	Rana and Noman, 2016

threshold level at 10 ppm for Ni and 50 ppm for Co has been proved undamaging for chickpea (**Table 2**; **Figure 1**). Ni at more than 50 µg Ni g^{-1} dry weight negatively affects growth of the plants at multiple levels such as morphological, physiological, and biochemical (Khan et al., 2006). Bakkaus et al. (2005) quoted average Co concentration for plants between 0.1 and 10 µg g^{-1} dry weights and also elaborated the beneficial role of Co for the normal metabolic functioning of plant at low concentration (**Table 2**; **Figure 1**). Whereas, several studies has been already proved the toxic effects of Co at higher concentration that become toxic for the normal plant growth and development and at the same time alters several processes inside plant cell (Parmar and Chanda, 2005; Jayakumar and Vijayarengan, 2006; Jayakumar et al., 2008; Khan et al., 2006; Khan and Khan, 2010). Jayakumar et al. (2008) reported the improved seed germination and increased length of radical and plumule of ragi and paddy at low dose of Co (5 µg L^{-1}) while reverse condition was observed at high dosage (25–100 µg Co L^{-1}). Cu in excess hinders plant growth and disables cellular processes such as photosynthesis electron transport (Yruela, 2005). Li et al. (2009) studied toxicity of Co on barley (*Hordeum vulgare* L.), oilseed rape (*Brassica napus* L.), tomato (*Lycopersicon esculentum* L.), and found out that Co has reduced the shoot growth and biomass of the plant (**Table 2**; **Figure 1**). Khan and Khan (2010) conducted an experiment on chickpea (*Cicer arietinum*) to evaluate the effect of nickel and cobalt at lower (0, 10, 50 ppm) and higher (100, 200, and 400 ppm) concentrations, obtained result indicated that at high concentration Ni and Co induced toxicity in chickpea plant by reducing its growth and biomass, seed germination, chlorophyll content, caused shoot, and root injury, leaf chlorosis, suppression of root nodules and finally it adversely affects the yield of the plant (**Table 2**; **Figure 1**). Cu when present in soil in high amount causes cytotoxic injury to plants this resulted in a hindrance of plant growth and caused chlorosis (Lewis et al., 2001). Copper toxicity adversely influence the growth, dry matter, and yield of *Vigna radiata* (Manivasagaperumal et al., 2011) and growth and oxidative mechanism of tea plant (*Camellia sinensis*; Dey et al., 2015). De Dorlodot et al. (2005) when plant is subjected to increased Fe^{2+} uptake and translocation by the plant, Fe toxicity appears (**Table 2**; **Figure 1**). Moreover, Arora et al. (2002) stated about the elevated Fe^{2+} level in plant induces the production of free radicals that causes membrane, DNA and proteins damages (**Table 2**; **Figure 1**). Wu, 2016) also studied iron toxicity in rice plant. Mn at higher level become toxic for plant induces several injuries such as the arrest of plant metabolic processes and the distortion in photosynthetic machinery (Ducic and Polle, 2005). Mn was also reported to inhibit root growth in soyabean (Chen et al., 2016). In excess Mn halt plant growth and development by causing interveinal and marginal chlorosis, necrosis, and distorted leaf structure both externally and internally (Kitao et al., 2001), also by reducing photosynthetic rate of the plant, CO_2 assimilation and stomatal conductance (Li et al., 2010). The level of 3.0 ppm of Mo on exposed metaltolerant hydrophyte, *Trapa natans* reported to cause distortion of mesophyll tissue in leaves, at 10 ppm cells get undifferentiated and at 50–600 µM concentration

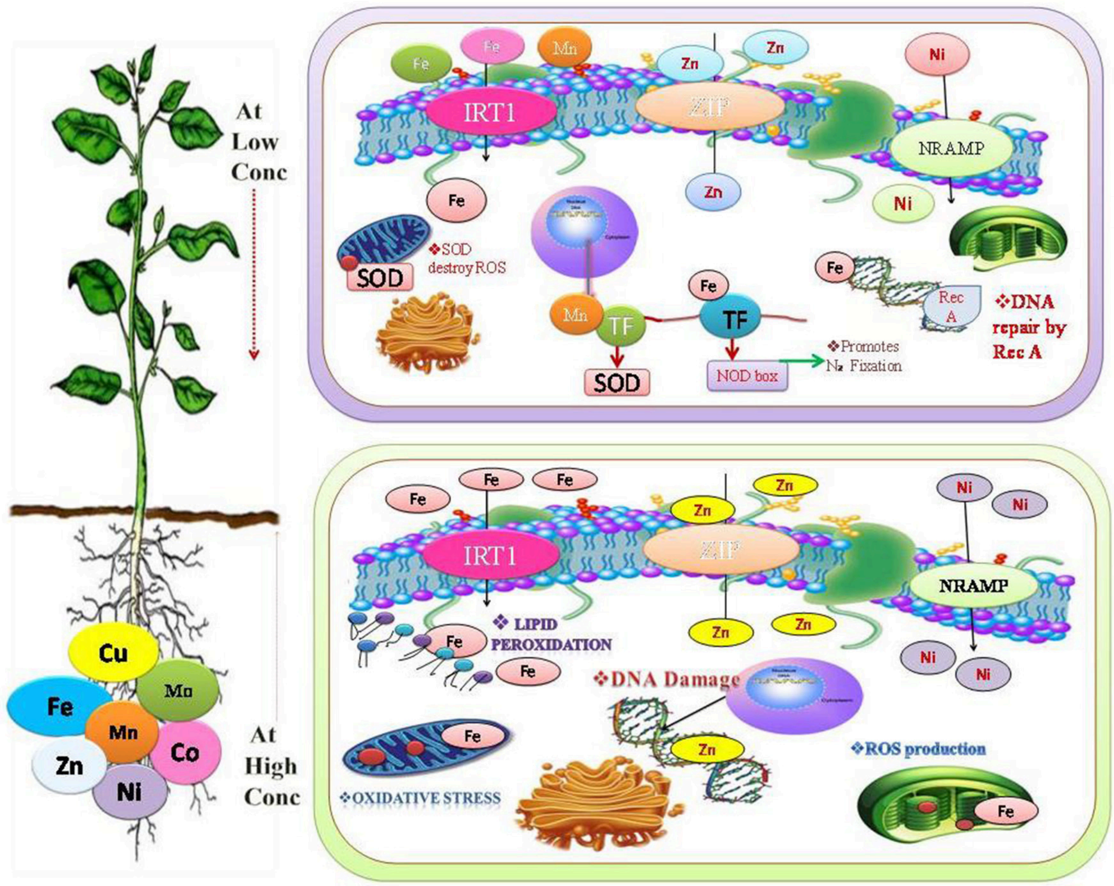

FIGURE 1 | Beneficial heavy metals are play a significant role at low concentration in the synthesis of protein, nucleic acids, photosynthetic pigment, and it also involved in the structural and functional integrity of cell membranes (Oves et al., 2016). Mn promotes antioxidant activity (Shenker et al., 2004), Fe promotes N_2-Fixation and DNA repair (Møller et al., 2007). While at high fconcentration it cause substitution of many essential functional groups, for instance, lipid peroxidation (LPO), cellular damage, generation of reactive oxygen species (ROS), disturbance in the various metabolic reaction by altering the enzymatic activity (de Oliveira Jucoski et al., 2013; Anjum et al., 2015).

of Mo caused alteration in the plant morphology, physiology particularly impaired photosynthetic activity (Baldisserotto et al., 2013). Mo in excess is a major factor in reducing plant growth and yield in poorly drained acidic soil, which is a suitable condition for the Mo availability (Rout and Das, 2002). Datta et al. (2011) reported that; in *Cicer arietinum* Mo concentration more than 7.5 ppm reduced the root and shoot length and at concentration more than 1.5 ppm altered the plant anatomy. Similarly Kumchai et al. (2013) illustrated his study in the context of high level Mo (10 mM) exposed to cabbage (*Brassica oleracea*), they reported the outcome of study that Mo decreased root and hypocotyls length and cotyledon length and also width (Datta et al., 2011). Izosimova (2005) reported the concentration of Ni (200–26,000 mg/kg) in contaminated soil, in comparison to optimum level Ni concentration (10–1000 mg/kg) in natural soil (**Table 2**; **Figure 1**). As stated by Rahman et al. (2005) Ni^{2+} at elevated level leads to numerous toxicities (chlorosis and necrosis) and physiological modification in plant species. Furthermore, Pandey and Sharma (2002) elaborated that in plant species Ni^{2+} provoke reduction of water content, this reduction is used to identify Ni^{2+} stress in plants. Theriault and Nkongolo (2016) reported about the Nickel and Copper Toxicity in White Birch (*Betula papyrifera*). According to the Warne et al. (2008) described that the increased concentration of Zn in soil hinders metabolic functions of plants that causes senescence and delayed growth. At increased concentration Zn create cytotoxic effect on plant growth and metabolism (**Table 2**; **Figure 1**). It leads to major changes in the nucleolus of the root tips cells, cortical cells displayed disruption, and dilution of nuclear membrane at 7.5 mM dose of Zinc (Rout and Das, 2009). Similar results were obtained by Liu et al. (2016) in *Solanum nigrum*.

AMELIORATING MECHANISM OF BENIFICIAL HEAVY METAL TOXICITY

HMs such as Co, Cu, Fe, Mn, Mo, Ni, and Zn are considered as beneficial elements that are required in small concentration by the plants, their concentration at high level become toxic for plant at multiple level (Asati et al., 2016). Thus, researchers through different studies suggested the various mechanisms to ameliorate HMs toxicity. Zeid et al. (2013)

TABLE 2 | Effect of beneficial heavy metal on different plants at high level.

Metals	Plants	Metal concentration at high level	Impacts on plant	References
Co	Mung beans	5 μM	Inhibited seedling growth. Caused chlorosis in young leaves. Reduced the Mn concentration in roots and Fe concentration in leaves thus inhibited plant growth.	Liu et al., 2000
Co and Ni	Maize genotypes	125, 250 mg/L Co 160 mg/L Ni	Showed negative effects on seed germination index, therefore reduced maize seed germination.	Ebru, 2014
Co and Ni	Chickpea (*Cicer arietinum)*	100, 200, and 400 ppm	Reduced Seed germination, plant growth, biomass production, and leaf chlorophyll content. Suppressed Root nodulation and decreased number of functional nodules.	Khan and Khan, 2010
Cu	*Phaseolus vulgaris*	500 μM	Reduced length and fresh and dry weights of the embryonic axis of germinating bean seeds. Decreased growth 50%. Increased level of albumin and globulin content	Karmous et al., 2015
Cu	*Withania somnifera*	200 μM	Reduced length of root, shoot, and leaf, and total number of leaves per plant. Decreased antioxidant activities. Alteration in protein profile	Rout et al., 2013
Fe	*Eugenia uniflora* L.	1.0 and 2.0 mM	Caused oxidative stress (production of ROS). Reduced root and shoot growth. Increased lipid peroxidation in leaves. Increased SOD and GR activity. Limited increase in CAT, POX, and APX activities while decrease in GPX activity. AA and GSH contents and the AA/DHA and GSH/GSSG ratios increased.	de Oliveira Jucoski et al., 2013
Fe	Sweet potato (*Ipomoea batatas* L.).	4.5, and 9.0 mmol L^{-1}	Decreased Height, leaf area, and total biomass. Decresed Mn nutrient concentration. Increased SOD and APX. Reduced stomatal densities. radical cells displayed mitochondrial impairment.	Adamski et al., 2012
Fe	potato (*Solanum tuberosum* L.)	0.1–2.0 mM	Hindered growth, reduced chlorophyll content in older leaves, and Hill reaction activity. Changed the behavior of enzymatic activities and Fe and Mn concentration. Decreased sugars, starch, and protein nitrogen content and elevated the level of non-protein nitrogen and phenols in tubers thus Reduced tuber yield and its quality.	Chatterjee et al., 2006
Mn	Tomato (*Lycopersicon esculentum*)	24.0 mg dm^{-3}	Reduced fresh weight of leaves, stalks, shoots and fruits, and biomass production. Declined quality and yield of tomato. Adversely affects nutrient uptake.	Kleiber and Graje, 2015
Mn	Chamomile (*Matricaria chamomilla*)	1000 μM	Hindered seedling growth. Caused oxidative stress and inhibit growth of seedling and plant. Decreased POD activity.	Kováčik et al., 2014
Mo	Black gram (*Vigna mungo* L.)	2 μm	Declined total dry matter, seed yield, and seed protein, increased activity of nitrate reductase. Reduced content of starch, sugars, protein, and nitrogen. Increasing electrical conductivity of seed leachate thus deteriorated seed quality.	Gopal et al., 2015
Mo	Chickpea (*Cicer arietinum* L.)	2 mg dm^{-3}	Reduced pod and seed yield, decreased the concentrations of starch, reducing, non-reducing, and total sugar content. Declined level of methionine, lysine, legumin, vicilin, total proteins, and protein and non-protein nitrogen in seeds. Deteriorated the seed quality by increasing the content of phenols, cysteine, and albumin.	Nautiyal et al., 2005
Ni	Maize (*Zea mays*)	200 μm	Decresed content of chlorophyll a and rate of Hill reaction. Increased K + efflux and carbohydrate leakage from roots and then cell death of root tips. Increased level of ROS generation.	Ghasemi et al., 2012
Ni	Potato (*Solanum tuberosum* L.)	0.5–0.5 mM	Decreased levels of sugars, starch, and protein nitrogen and elevated accumulation of non-protein nitrogen and phenols in tubers. Increased non-reducing sugars, starch, and phenols levels in leaves.	Shukla, 2010
Zn	Wheat seedling (*Triticum aestivum*)	3 mM	Decreased total chlorophyll content and chl a, and chl b. sygnificantly increased MDA and H2O2 content in leaves. Increased level of soluble sugar and proline in both leaves and roots. Inhibited POD and GR activities.	Li X. et al., 2013
Zn	Tea (*Camellia sinensis* L.)	30 μM	Reduced shoot and root fresh and dry weight. Disorganization of cellular organelles occurred. Reduced net photosynthetic rate, transpiration rate, stomatal conductance, and chlorophylls a and b contents. Caused oxidative damage Elevated the level of ROS generation.	Mukhopadhyay et al., 2013

ameliorated the cobalt toxicity from *Medicago sativa* by giving the pretreatment of the HMs solutions with precipitation and EDTA (Ethylenediaminetetraacetic acid) that reduced their retarding impact on growth and the metabolic activities. Li et al. (2008) through their experiment on copper stressed *Arabidopsis thaliana* alleviated the Cu toxicity by using silicon. Thus, Si (Silicon) decreased the leaf chlorosis, and enhanced root-shoot biomass. It also reduced the stress induced enzyme (phenylalanine ammonia-lyase). Si declined the RNA level of *Arabidopsis* copper transporter genes; copper transporter 1 (COPT1) and heavy metal ATPase subunit 5 (HMA5). Therefore, Si proved to improve the plant resistance to Cu toxicity at multiple levels. Exposure of liming to *Juglans regia, Robinia pseudoacacia, Eucalyptus* sp., and *Populus* sp. plantations reported to alleviate Mn and Cu toxicity (Chatzistathis et al., 2015). Hajiboland et al. (2013) reported about the role of aluminum (300 μm) in reducing Fe toxicity in tea plant. Whereas, Dufey et al. (2014) reported the application of Si on rice plant to reduce the Fe generated toxicities. Rogalla and Römheld (2002) studied the toxic effects of Mn from low to high concentration (0·5–1000 μM) in *Cucumis sativus* supplied with Si as sodium silicate at 1.8 mM concentration, which reduced the generated stresses by decreasing Mn in intercellular washing fluid, mainly in the barium chloride ($BaCl_2$) and DTPA (diethylenetriaminepentaacetic acid)-exchangeable fraction of the leaf apoplast, in symplast area. Similar study was also reported by Maksimović et al. (2012) in Cucumber (*Cucumis sativus*). Si is also known to mitigate manganese mediated toxicities in plants (Liang et al., 2007). Kumchai et al. (2013) studied the role of proline to partially prevail over molybdenum induced stress in cabbage seedling. Plant hormone Gibberellic acid has the potential to alleviate Ni induced stress; it has been proven by the Ali et al. (2015) in mungbeen plant. They further propounded that the application of gibberellic acid on mungbeen improved plant growth and yield. Similarly, another phytohormone jasmonic acid was reported to amend plant growth parameters by reducing Ni mediated toxicity in *Glycine max* (Sirhindi et al., 2015). While Siddiqui et al. (2013) reported about the beneficiary role of salisylic acid and nitric oxide (NO) in mitigating Ni stress in wheat. Kaya et al. (2009) gave the exogenous application of Si (1.0 mM) in maize plant grown in high zinc concentration that enhanced plant growth, chlorophyll content, and relative water content whereas reduced the membrane permeability and proline content. Another study was done by the researchers to alleviate Zn induced oxidative stress in radish (*Raphanus sativus*) seedling with the help of plant stress hormone 24-epibrassinolide, that reported to activated the antioxidative enzymatic system (Ramakrishna and Rao, 2012).

CONCLUSION AND FUTURE OUTLOOK

Soil serves the most important component accruing considerable amount of hazardous chemical pollutants from varying sources per year. Besides behaving as an oversized sink for chemical pollutants soil also serves as a natural buffer by governing the overall transport of chemical substances to the environment. Plants reflect frequent sensitivity to both low and high level concentration of heavy metals, at low level they serves as propitious constituent for plant growth and development but on increasing its concentration beyond threshold limit it will imposes several inimical impacts in plant constituely thereby adversely influencing the soil fertility and development. Slow but perpetual contamination of agricultural soil with heavy metal pollutant may significantly harm the environment and posess the major threats to public health and also build the major issues for subsequent discussion, as it gets accumulated in the soil and shows significant accumulion in agricultural crops. According to the report of FAO (food and agriculture organization of UN) (2009) world population is increasing at a rapid rate and is predicted to reach about 9.6 billion till 2050. Therefore, the future global challenge is to mask the world's hunger through sustainable agriculture and food production. Some HMs such as Co, Cu, Fe, Mn, Mo, Ni, and Zn are considered as beneficial for plant growth and development. Plants require them in a limited quality. Whereas, at high level these metal ions tends to create differential level of toxicity in plant that in turn leads to inhibited plant growth, halt enzymatic and metabolic pathways and also create damages to plant morphology and physiology that eventually reduced overall plant productivity.

Therefore, based on the credible number of research reports it could be well-demarcated that only a required amount of heavy metal could revamp the physiological and morphological characteristics of plants. Thus, it will become essential to exaggerate the further programmes for the improved comprehension of whole mechanism lying behind the synergistic and antagonistic action of heavy metals on plants to perpetuate the ecological harmony of the globe. Considering future perspectives, an efforts should be made to completely alleviate the exagregated level of essential metal ions induced toxicity within the plant tissue. Revealation of transportation mechanism at molecular level should also be made effective in context to plant beneficial HMs ion, as well as reliability of one metal ion on the homeostasis of other metal ion. There is a need of much elaborated research on the mechanism of metal uptake and translocation in relation to their impact on plant growth and development is required to keep pace with healthy agricultural production.

AUTHOR CONTRIBUTIONS

NA, VY, ShwS, RM, PA, SwS, and DT designed the manuscript, NA, VY, SwS, and DT wrote the manuscript. DT, NKD, PA, ShiS, and DC critically evaluated the manuscript.

FUNDING

Authors are thankful to the University Grants Commission, New Delhi for financial support. DT: Further extends his thanks to the University Grants Commission for providing Dr. D. S. Kothari Post-Doctoral Fellowship.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fenvs.2016.00069/full#supplementary-material

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.