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REVIEW

Effect of Heavy Metals on Growth and Development of Cultivated Plants with Reference to Cadmium, Chromium and Lead – A Review

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Heavy metals are elements that are naturally present in the environment. However anthropogenic activities such as the production of industrial wastes and domestic effluents, dumping of sewage waste, urban storm, water runoff, and atmospheric sources can give rise to the concentration of these metals relative to the normal background values. Any metal or metalloid with a density exceeding 5g /cm^{-3} is termed as "heavy metal". These metallic ions are always associated with pollution and toxicity, although some of these elements are required by organisms at low concentrations. Some of the heavy metals such as zinc, iron and copper are essential for the physiological functioning of living organisms. The same essential elements become toxic when their concentration increases from their initial value. The present review article features the occurrence and toxicity of various heavy metals and compiles the sources, effects and the treatment of heavy metals with reference to cadmium, chromium and lead. This work also investigates the abilities of plants in terms of tolerance and degradation of these metals. It also reviews deeply about the heavy metal uptake mechanisms and several research studies associated with the topics. An evaluation of the present status of technology exploitation and the capability of some cultivated plants to reduce the contaminant is also reported and suggested for future work.

Key words: Anthropogenic, cultivated plant, heavy metals, toxicity

1. Introduction

The beginning of the industrial revolution has led to an increase in the concentration of heavy metals in the biosphere and has become a serious concern to the environment. Yoon *et al.* (2006) state that the contamination by heavy metals can be considered as one of the most significant threats to water and soil resources as well as to human health. Over the past 200 years, especially the activities of humans have resulted in the enormous release of heavy metals into the environment. Heavy metal ions uptake by cultivated plants is the main pathway entry into animals and humans (Roth *et al*., 2006). Contamination of ecosystems and the action of toxic metals on plants and animals is one of the major problems all over the world.

All the metals in the periodic table whose atomic number is greater than 20, except the alkali metal and alkali earth are treated as heavy metals. Table 1 elaborates on a list of heavy metals, their year of discovery and the scientists who discovered them. Several of these ions in trace amounts are required for metabolism, growth and development. However, troubles occur when the amount of these vital ions increases which leads to cellular damage (Schutzendubel and Polle, 2002).

Classification of different heavy metals based on their roles for biotic systems has been shown in Figure 1. Biotic organisms need different amounts of heavy metals. Lane and Morel (2000) listed that iron, cobalt, copper, manganese, molybdenum and zinc are required by humans. Cadmium (Cd), copper (Cu), nickel (Ni) and zinc (Zn) are considered highly toxic since they cause lethal effects in the living system. There is an excess release of heavy metals such as cadmium, chromium, copper, iron, lead, mercury, nickel, zinc, etc., particularly in areas with higher anthropogenic activity. The exposure of humans to heavy metals can occur through a variety of routes, which includes ingestion through drink and food or inhalation. Continuous exposure of such heavy metals can have serious health issues on human life, soil, air and aquatic biota. Certain plants and microbes can be used as agents in the conversion of these toxic into non-toxic forms. The practice of bioremediation uses different agents like yeast, fungi, algae etc., as major tools in treating heavy metals present within the environment.

2. Sources of heavy metal pollution

Anthropogenic and geological activities are the major sources of metal contamination. Jadia and Fulekar (2009) stated that industrial pollutants, mining, military activities, fuel production and agricultural chemicals are some of the human activities which cause metal contamination. Burning of petroleum fuels was also contributing to toxic waste (Knittel, 2011). Industrial processing of plastics, textiles, wood preservation and paper processing also serves as a source of metal contamination (Nagajyothi *et al*., 2010). Helmisaari *et al*. (1995) also reported that mine tailings, smelting, refining and transportation contribute to metal contamination. According to Geiger (2010), both natural and man-made processes result in metal-containing airborne particulates. Depends on the climatic conditions, the particulates may become wind-blown or recycled to the lithosphere as precipitations by rain or snowfall (Nagajyoti, 2010). Domestic effluents probably constitute the largest single source of elevated metal values in rivers and lakes.

The use of detergents also produces a possible pollution threat. Bradford (1997) revealed urban stormwater runoff has long been recognized as a major source of contaminant to surface waters. Agricultural lands are also polluted by metals, originating from pesticide applications and by the usage of chemical fertilizers and irrigating the land with wastewater of poor quality or by the addition of sewage sludge. Soil erosion also accounts for the process. Wind and water are the two main agents for soil erosion. Sardar *et al.* (2013) reported that some aerosol substances carry different kinds of the contaminant like smog cloud and heavy metals. These forms of heavy metal get deposited on leaf surfaces in the form of fine particulates and can enter the leaves via stomata. Yanqun *et al*. (2005) reported that cadmium enrichment also occurs due to the usage of sewage sludge, manure and limes. Trace metals are natural components of the environment, but elevated and potentially toxic levels occur sometimes. Agriculture, mining, industry or transport leads to acidic soils in which elevated levels of soluble metals especially Al or Mn may occur, while high concentrations of other metals such as Cu or Pb may be present in sites contaminated.

Due to excessive anthropogenic activities, the natural geochemical cycle is greatly disturbed and results in deposition of one or more metals in the soil and waters (Sumner, 2002). The essential metals start functioning as heavy metals when their levels become significantly high due to increased human activities which are taken up by the plant and circulated through the food chain. Table 2 lists out some of the important sources and the related different heavy metals released associated with it.

2.1. Sources of cadmium toxicity

Cadmium (atomic weight 112.40, sp. gravity 8.65 mg m^{-3}) the group II B transition element is relatively rare in the earth crust. Azad *et al.* (1986) noted that in natural soils, the amount of Cd varies with the type of source materials. The concentration is high in soils derived from basaltic rocks and low from granitic rocks respectively. An increase in submergence decreases the availability of Cd. cadmium mimics Zn in its behavior, but in excess Cd seems to be toxic to biotic life.

Valls and Lorenzo (2002) stated that Cadmium pollution causes deleterious effect on public health and wildlife due to its greater solubility in water, which has led to increase interests for improvement of such techniques that can trim down its toxic effects in soil. Cadmium is one of the highly toxic metal pollutants present in the environment (Wagner 1993). Williams and David (1973) observed that although Cd occurs naturally in low concentration in agricultural soil, its level has been steadily increased due to the application of sewage sludge, city wastes and Cd-containing phosphatic fertilizers.

2.2. Sources of chromium toxicity

In nature, chromium is found in the form of ore and not as free element. Chromite ($FeCr_2O_4$) is one of the main ore of chromium. Costa and Klein (2008) reported that French chemist Nicolas – Louis Vanquelin, first discovered elemental chromium in Siberian red lead ore crocoite in 1797. Losi *et al. (*1994) found that these are natural elements in crystal abundance, which is found in all phases including air, water, soil and biota. They also reported that all metallurgical, chemical and refractory brick industries are the major industries using chromium. Ghani (2011) reported the use of chromium on a large scale in several industries like electroplating, metallurgy, production of paints, pigments, tanning, chemical production, pulp and paper production has also resulted in the contamination of soil and water. Oliveira (2012) found that chromium (VI) in the forms of chromate, dichromate and CrO_3 is considered as highly toxic forms in nature.

2.3. Sources of lead toxicity

Lead (Pb) is omnipresent and were used as antiknock agents in gasoline until 1989. It is estimated that 4.5 to 5.5 million tons of lead used in gasoline remain in soil and dust. Distinctive properties of lead like softness, high malleability, low melting point and confrontation to corrosion, have resulted in its extensive usage in diverse industries like automobiles, ceramics, plastics, etc. This sequentially has led to a manifold increase in the occurrence of free lead in biological systems and the static surroundings. Lead is known for its effective occupational toxic chemical and its related manifestations. The non biodegradable nature of lead is the principal reason for its delayed perseverance in the environment. The principal reason for its belated perseverance in the environment is due to its non biodegradable nature of the metal. Human exposure to lead occurs through various sources like leaded gasoline, lead-industrial processes such as smelting, combustion and lead-based products like paints, pipes or solder in water supply systems (Flora *et al.*, 2012).

3. Heavy metal stress and plant response

Vangronsveld and Clijsters (1994) reported that oxidative stress can be defined as the physiological changes resulting from the formation of excess quantities of reactive oxygen species (ROS). Maksymiec *et al*. (2008) found that higher plants produce ROS during different metabolic processes in cellular organelles but their rate of production is dramatically elevated under heavy metal stress. They also found that these metals are known to cause oxidative toxicity in plants. Several studies suggested by Gill and Tuteja (2010) shows that in plants, toxicities associated with heavy metals may be at least in part due to oxidative damage. Shaw *et al*. (2008) observed that heavy metal may induce oxidative damage due to two reasons: (1.) As a result of augmentation in the making of ROS and (2.) As a result of the slowing down of ROS. Schwartz *et al*. (2003) found that in plants, heavy metals may enhance the production of ROS by interfering with the respiratory and photosynthetic process. Zacchini *et al*. (2003) found that plant cells acquire an efficient antioxidant defense system comprising enzymes namely catalase (CAT), guaiacol peroxidase (Gu–POD), glutathione reductase (GR), ascorbate peroxidase (APx) as well as non–enzymatic antioxidant such as glutathione (GSH), ascorbate (ASA), tocopherol, carotenoids, proline, phenols and polyamines to counter the harmful effects of ROS.

Gamalero *et al*. (2009) found the changes in the ultrastructure, biochemical and at molecular levels occurs in the cells and tissues of plants are brought about by the presence of heavy metals. Gratao *et al*. (2005) reported that different metals can cause oxidative stress and their mode of action varies depends on plant species, type of metal, period of exposure, age of the plant and growing media. Zacchini *et al*. (2003) confirmed the available data in the literature which confirms an increase in antioxidant activity in the course of heavy metal stress. Chakraborty and Pradhan (2012) observed the oxidative damage as malondialdehyde (MDA) content, which is a product of lipid peroxidation.

3.1. Mechanisms of heavy metal uptake and accumulation by cultivated plants

Several researches have studied about the uptake of heavy metals and its mechanisms in plants. It could be used to enhance the factors to develop the uptake of elements by plants. The plants can either accumulate the metal (accumulators) within them or exclude (excluders) out (Sinha *et al.,* 2004). These plants are capable of degrading the contaminants into inert forms in their tissues. The excluders check contaminant uptake into their biomass. Plants use specialized mechanisms to derive essential micronutrients from the surroundings, even when present at low ppm levels. These similar mechanisms are also involved in the uptake, translocation and storage of toxin, whose chemical properties imitate those of essential elements. Thus, micronutrient uptake mechanisms are of immense significance to phytoremediation.

Salido *et al*. (2003) reported that water evaporating from the leaves of the plant, serves as a drive to absorb nutrients and other soil substances into plant roots. The process termed as evapotranspiration is responsible for moving contamination into the plant shoots as well. As the contamination is transported from roots to the shoots when harvested, contamination is removed while leaving the original soil without any disturbance. Some plants are also are termed as “hyperaccumulators” which achieves a shoot-to-root metal absorption ratio greater than one. Ideally, Salido also reported that hyperaccumulators which thrive in toxic environments require little maintenance and produce high biomass.

Erdei *et al.* (2005) observed that metal accumulating plant species can intentionally take heavy metals by 100 or 1000 times better than those taken up by excluder plants. Microorganisms like bacteria and fungi which lives in the root region closely associated with plants may contribute to mobilizing metal ions. Microbes play a promising role in eliminating organic contaminants than the inorganic compounds.

Plants used for phytoextraction should be forbearing to the high concentration of metals without considerable inhibition of growth or reduction in biomass production. McGrath *et al.* (2002) hence proved, the level of accumulation of heavy metal varies between and within different species. Yoon *et al. (*2006) stated that it is significant to use native plants for phytoremediation because these plants are often superior in terms of survival, growth and reproduction under environmental pressure than plants introduced from other environments. Wodaje and Alemayehu (2017) studied the heavy metals toxicity of garlic. Sinhal *et al.* (2011) revealed that remarkable amount of Pb was accumulated in different parts of *Helianthus annuus* by atomic absorption spectrophotometer studies. The heavy metal was more concentrated in the roots in comparison to shoot and leaves. Roughly 90% of Pb accumulation occurred in the roots of Indian mustard (Liu *et al.,* 2000).

Sanita di Toppi and Gabbrielli (1999) stated that a high amount of cadmium in plants reduces the growth in root and shoot causes leaf rolling and chlorosis. It has been reported in maize, that the plant is having the more tolerant to take out the multi-metals like (Cu, Cd, Pb and Zn). In *Sesbania virgata,* Cobbett and Goldsbrough (2002) carried out an experiment, which results in the higher accumulation of chromium by roots than the shoot system. Singh *et al.* (2009) observed that the uptake of cadmium by *Alfalfa* plant shows a significant increase in the level of metal toxicity in root and shoots has been found with increase in metal concentrations. Ahmad *et al.* (2011) mentioned that chromium was accumulated in the shoots, root and seeds of rice plants. During 120 days of disclosure treatment, heavy metal cadmium was washed-out from the contaminated soil, signifying absorption of cadmium metal by *Sesbania* plants (Bakiyaraj *et al.* 2014b). It has been well-known that *Sesbania sesban* is an appropriate plant for phytoremediation which accumulate a higher concentration of cadmium metal from the soil contaminated with metals.

Metal ions are part of the natural environment. Plants uptake and accumulate these metals and bring about the entry of poisonous elements to the food chain, posing a critical threat to humans. Anthropogenic activities such as the use of contaminated water in agriculture, excessive mining and industrial activities lead to heavy metal pollution (Singh *et al*., 2004). Kabata-Pendias *et al*. (2001) states that the improper disposal of wastes and excessive use of pesticides was one of the most significant sources of heavy metal pollution in the environment. Heavy metals such as Cd, Pb, As, Cr and Hg are often listed as primary contaminants of concern. According to Oncel *et al.* (2000) and Iniebiyo and Atieme (2018), the plants uptake these metal ions from the soil and bioaccumulate these into their tissues and bring about a notable reduction in their vegetative growth and yield of grains. Panda *et al*. (2003) reported that these are lethal to the synthesis of chlorophyll and photosynthetic activity. Metal accumulation is so far reported more in dicotyledonous crop plants than monocotyledonous plants (Kabata – Pendias *et al*., 2001).

3.2. Histochemical localization of heavy metals in plants

Glater and Hernandez (1972) observed the deposition of lead on plant tissue by using histochemical methods which are considered to be rapid, easy and precise. They also proposed a modified method for sample preparation. Sodium rhodizonate is a particular colour giving reagent that gives red color with a buffer solution at pH of 2.8. Staining the tissues with sodium rhodizonate gives pink-purple, red-brown to blackish brown in tissues that accumulate lead.

Charlotha *et al*. (2016) observed the anatomical structure of roots in *Thalassia hemprichii* which showed some changes in the tissues on exposure to lead. The deposition of lead on root tissues can be spotted including the three layers namely epidermal, exodermal, endodermal layers and at the vascular systems. The colour intensity of staining depends on the concentration of the metal. Exodermis and endodermis tissue were thickened which indicates the translocation of this particular metal. The deposits of lead were more on the cell walls and the spaces between cells. Lux *et al.* (2004) also proved that in apoplast, exodermis and endodermis play a key role in protection against various kinds of strain experienced by the plant.

Tung and Temple (1996) stated that the deposition of lead in apoplastic seems to be the main way of deposition in root tissue. The lead will continuously be uptaken and translocated into the cell wall and the amount of lead deposition increases with the increase of metal concentration. Gomes *et al*. (2011) noted that the exodermis and endodermis of *Brachiaria decumbens* found to have excellent capability to confine the flow of metal into the apoplast, and thickens the cell wall in the root to provide space for withholding of heavy metals, thereby reducing the metal translocated to the leaves. Barber (1995) observed that mineral translocation in roots was greatest when the growth rate, water pressure and transpiration rate is high.

The rhizome of *T. hemprichii* shows thickening in the Cortex cells. Air space was enlarged. These changes may be due to lead bound to the cell walls of the cortex and disruption of the hormonal balance (Charlotha *et al*., 2016). Changes in the cortical parenchyma cells and air space stems of aquatic plants *Potamogeton* sp. (Al-Saadi *et al*., 2013) finalized that the change was due to the metal accommodation to the cell wall and the space between cells and verifies the correlation between metal tolerances in wetland plants. Additionally, they also found that the formation of the air space was one of the important strategies of wetland plants getting used to the conditions underwater, which not only enhances the flow of oxygen to the plant but also increases the possible loss of oxygen to the regions around the root.

Leaves internal structure in *T. hemprichii* shows changes at cuticle layers and epidermis cells according to metal toxicity. Lead enters the leaf tissue through the cuticle was marked with red deposit in the layer. The binding at the epidermal cells was used as a criterion to prevent that lead going further into the chloroplast cells. As the lead accumulation goes up, cuticle layers and leaves epidermis became thicker. The metal makes its entry through the stomata of the leaves tissue. As stomata of the leaves are larger than lead particles, the lead particles simply fit into the tissues of the leaf. T. hemprichii is a aquatic plant which shows absence of stomata but has a slender cuticle as the entry point where the metal travels and trapped in the cavity which is indicated by thickening of the cuticle (Charlotha *et al*., 2016).

Larkum *et al*. (2006) proved that lead is capable of interrupting the entire process of photosynthesis if it enters the cells of chloroplast. Sridhar *et al*. (2005) stated that the revelation of heavy metals on plants will lead to a decline in the size of mesophyll cells and these problems can lead to the collapse of the mesophyll tissues of leaves. Reduction of epidermal cells and the aerenchyma will ultimately leads to the reduction of leaf thickness (Al-Saadi *et al*., 2013). Sandalio *et al.* (2001) proved the reduction in the number of elements of the xylem in response to heavy metal was an adjustment to maintain the flow of water on the plant.

Table 1. Discovery of heavy metals (Andraos, 2005)

Heavy metals	Year of Discovery	Scientist discovered
Arsenic	1250	St. Albertus Magnus
Cadmium	1817	Friedrich Stromeyer, Sir Humphry Davy
Chromium	1797	Louis Nicolas Vauquelin
Cobalt	1735	Georg Brandt
Iron	2500 BC	Not available
Lead	1000 BC	Not available
Manganese	1774	Johan Gottlieb Gahn
Mercury	1500 BC	Not available
Molybdenum	1781	Peter Jacob Hjelm
Nickel	1751	Axel Fredrik Cronstedt

Table 2. Sources of different heavy metals from different samples

Sources	Heavy metals	References
Aerosol emissions	Ni, Zn	Pant and Harrison (2012)
Animal manure	Mn, Zn, Cu, Co	Verkleji (1993)
Burning of coal	Cd, Hg, Mn, Ni, Al, Fe, Ti	Lokeshappa and Dikshit (2012)
Burning of oil	V, Fe, Pb, Ni	Nagajyoti (2010)
Diesel engines	Cu, Cd	Pant and Harrison (2012)
Enzyme detergents	Fe, Mn, Cr, Co, Zn, Sr, B.	Angino *et al*. (1970)
Galvanised metals	Zn	Nagajyoti (2010)
Lubricants from vehicles	Cd, Cr, Hg, Ni, Pb, Zn	Nagajyothi (2010)
Metal emissions	Ni, Zn	Pant and Harrison (2012)
Nuclear power stations	Se, B, Cd, Cu, Zn, Cs, Ni	Verkleji (1993)
Phosphate fertilizers	Cd, Cu, Zn, As	Zarcinas *et al*. (2004)
Sewage sludge	Zn, Cr, Pb, Ni, Cd, Cu	Verkleji (1993)
Volcanic eruptions and forest fires	Cd, Cu, Ni, Pb, Zn	Lin and Pehkonen (1998)

Table 3. Effects of cadmium, chromium and lead on the growth and development of plants

Plant species	**Effects**	**Reference**
	Cadmium	
Abelmoschus esculentus	Shoot length, root length, fresh weight and dry weight was gradually decreased with increasing in the concentration of heavy metal	Murugalakshmikumari and Ramasubramanian (2014)
Brassica juncea	Decline in the length of root ranging from 17-54% at the pre-flowering stage; decline in the length of the shoot from 4-5% during post flowering stage	John *et al.* (2009)
Cicer arietinum	Growth parameters like vegetative growth, fresh weight, dry mass have been reduced	Hayat *et al.* (2013)
Dalbergia sissoo	Reduction the length of shoot	Shah *et al.* (2008)
Helianthus annus	Reduced plant height	Chaves *et al.* (2011)
Phaseolus vulgaris	Decrease in growth and development Alternation in catalytic efficiency of enzymes	Somasekharaiah *et al.* (1992)
Phyllanthus amarus	Significant decrease in root and shoot length and fresh and dry weight	Rai *et al.* (2005)
Pisum sativum	Alternation in catalytic efficiency of enzymes	Romero-Puertas *et al*. (2004)
Solanum melongana	Adversely affects the germination, seedling length and number of lateral roots	Neelima and Reddy (2002)
	Chromium	
Caesalpinina pulcherrima	Inhibition in the root length	Iqbal *et al.* (2001)
Curcuma sativus	Significant reduction in the height of the plant	Gorsuch *et al.* (1995)
Dalbergia sissoo	Reduction in the length of shoot	Shah *et al.* (2008)
Lactuca satirus	Reduced plant height	Gorsuch *et al.* (1995)
Panicum miliaceum	Reduction in the height of the plant	Gorsuch *et al.* (1995)
Salix viminalis	Root length was most affected	Prasad *et al.* (2001)
Vigna radiata	Affects the shoot and root development; Affects germination and seedling growth	Shagnar *et al.* (1997)
	Lead	
Allium porrum	Inhibits root and stem elongation and leaf expansion	Gruenhage and Jager (1985)
Hordeum vulgare	Inhibits root and stem elongation and leaf expansion	Juwarkar and Shende (1986)
Lactuca sp. and *Daucus* sp.	Significant reduction in growth of roots	Baker (1972)
Pinus helipensis	Inhibits seed germination	Nakos (1979)
Pisum sativum	Irregular radial thickening in roots	Paivoke (1983)
Sesamum indicum	Inhibition of root growth	Kumar *et al.*(1992)
Spartiana alterniflora	Inhibits seed germination	Morzck and Funicclli (1982)

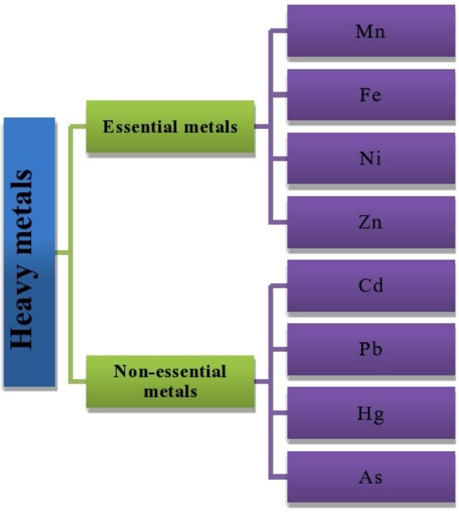

Figure 1. Classification of heavy metals on the basis of their roles in living systems.

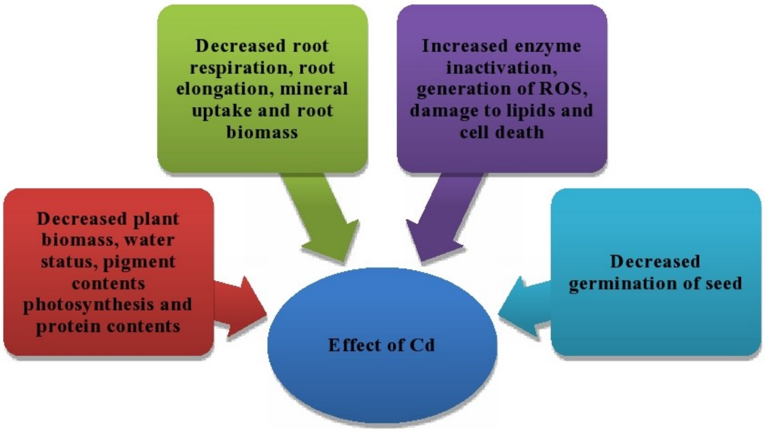

Figure 2. Effects of cadmium in plants.

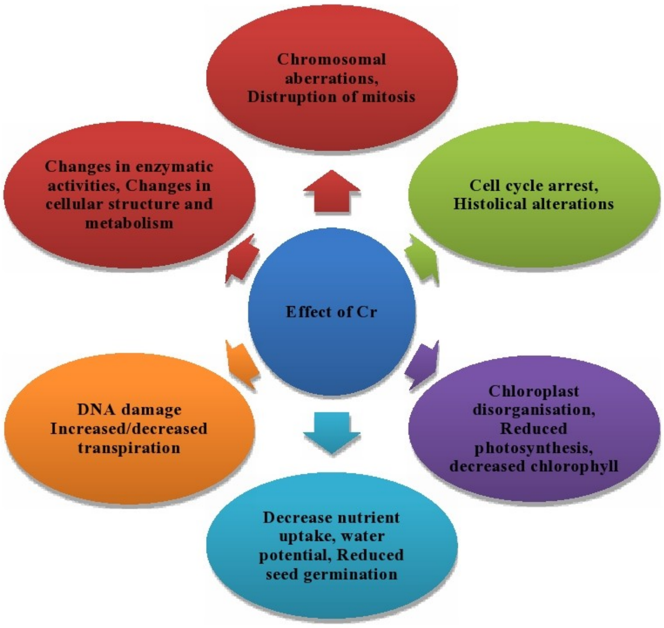

Figure 3. Effects of chromium in plants.

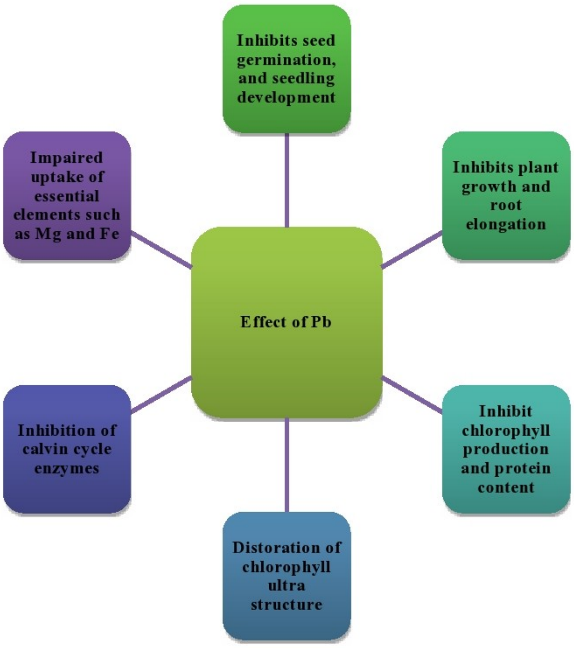

Figure 4. Effects of lead in plants.

According to Charlotha *et al*. (2016), lead that travels along with water and nutrients through the cuticle and epidermis will gather on the cell walls, then passes through water transportation to the stele. Afterward, red stain will be seen in the cell walls of the diaphragm which indicates the deposition of lead. The strap of metal on the walls of parenchymal cells and air space of cortical layer stem of *Potamogeton* sp. is a likely approach of the accumulator species. These red streaks were also seen on the stele and vascular bundle. This results in the enlargement of the air spaces of protoxylem as well as the phloem sieve elements (Al-Saadi *et al*., 2013).

4. Growth and developmental effects of heavy metals on cultivated plants

The exposure of plants to poisonous levels of heavy metals triggers a wide range of physiological and metabolic alterations (Villiers *et al*., 2011). Different heavy metals have varying sites of action inside the plant host, thereby the entire visual toxic response differs between heavy metals. Prolonged exposure and higher accumulation of such heavy metals can have deleterious health effects on human life, soil, air and aquatic biota (Ravindra Singh *et al.,* 2018). The most widespread visual evidence of heavy metal toxicity is a reduction in plant growth including leaf chlorosis, necrosis, turgor loss, a decrease in the rate of seed germination and a crippled photosynthetic apparatus, often interrelated with succeeding senescence processes or with plant death (Dalcarso *et al*., 2010). Gamalero *et al*. (2009) also stated that these are associated to ultra structural, biochemical and molecular changes in plant tissues and cells brought about by the occurrence of heavy metals.

Kaushik *et al. (*2005) reported that wheat plants treated with metal fixed textile effluents showed additional growth in shoot length. When *Clitoria ternatia* plant was treated with metal contaminant, the shoot length of the control plant was 2.1 cm and the treatment plant is about 1.3 cm. The shoot length was reduced in treated seedlings when compared to control. The root length of the control plant is 1.3 cm and treatment is 0.7 cm. The root length was reduced by 53.8% in treated seedlings when compared to control seedlings (Priya and Balakrishnan, 2014).

Agricultural soil is contaminated by heavy metals is one of the critical environmental distress due to their potential poor ecological effects. These poisonous metals are considered as soil pollutants due to their extensive occurrence and their acute and chronic lethal effect on plants grown of such polluted soils. Table 3 indicates the different heavy metals such as Cd, Cr and

Pb and their effects on plants.

4.1. Effects of Cadmium

Cadmium influence *plant* growth negatively and its toxicity can be detected at both morphological and physiological levels. Salt *et al*. (1995) suggested the regulatory limit of cadmium (Cd) in agricultural soil is 100 mg/kg soil. Alcantara *et al*. (1994) observed that the inhibition of root Fe (III) reductase stimulated by Cd led to Fe (II) deficiency and it critically affects photosynthesis. Das *et al*. (1997) has shown that Cd meddles with the uptake, transport and use of several elements (Ca, Mg, P and K). According to Hernandez *et al*. (1996) Cd also inhibits the activity of nitrate reductase enzyme and decrease the absorption and transport of nitrate from roots to shoots. Fodor *et al*. (1995) listed that in wheat and sunflower plants, cadmium treatments revealed to bring down the activity of ATPase and also produces alterations in the membrane functions by inducing lipid peroxidation.

The germination pattern was greatly affected by the increased concentration of heavy metal contaminated soil. It inhibits the growth completely at the highest concentration of cadmium in the soil (Bhardwaj *et al.,* 2009). Seed germination and seedling growth was greatly affected by the increased concentration of aluminum and cadmium. Swamy *et al.* (2011) observed that plants in response to cadmium show a considerable reduction in the germination of seeds. Farouk *et al.,* (2011) investigated decrease in chlorophyll content in Cd treatment (100 and 200 mg $CdCl_2$ kg-1 soil) after 45 days of cultivation in *Raphanus sativus*.

Sanita di Toppi and Gabbrielli (1999) and Baker *et al. (*1994) reported that cadmium can inhibit root and shoot growth and yield production. It affects nutrient uptake, gets frequently accumulated and then enters the food chain with a significant potential to impair animal and human health. Sanita di Toppi and Gabbrielli (1999) found that there is a general agreement that high Cd concentration retards metabolic activities and cause the death of the plants. Bharadwaj and Marcarenhas (1989) stated that Cd inhibits chlorophyll synthesis, activity of photosynthesis I and II. Padmaja *et al. (*1990) stated reduction of biomass by Cd toxicity could be the direct consequence of the inhibition of chlorophyll synthesis and photosynthesis. Sandalio *et al. (*2001) found that excessive amounts of Cd may also cause decreased uptake of nutrient elements, inhibition of various enzyme activities and induction of oxidative stress including alterations in the enzymes of the antioxidant defence system. Negative impact of cadmium in growth and development of plant was elaborated in Figure 2.

4.2. Effects of chromium

Mohanty and Patra (2013) noted that chromium is a well documented toxic agent for the growth and development of the plant. Besides, Singh *et al.* (2013) observed that it is known as one of the causes of environmental pollution. Hawley *et al*. (2004) stated that under reducing condition, Cr^{6+} is transformed to its more lethal form Cr^{3+}, which can ultimately influence and change soil pH to both alkalinity and acidity extremes, depending on the existing condition in soil subsurface. The above mentioned fact might disturb the nutrients bioavailability and their sorption by plants. Oliveira (2012) stated that immobilization of chromium in the vacuole of plant root cells is suggested as the main reason for the disproportionate accumulation of this metal in roots.

The germination percentage is inversely proportional to the concentration of chromium (Bakiyaraj *et al.,* 2014a). Gbaruko and Friday (2007) reported that increased concentration of chromium can cause stunted growth in plants. Shah *et al. (*2010) have found that plant roots show more rapid changes in growth patterns than shoots. Total chlorophyll content increased slightly and then decreased in the leaf after treatment irrespective of the concentration of chromium (50, 75, 100 mg kg^{-1}) while an increasing trend was noticed in the stem (Chinmayee *et al.,* 2014).

As a consequence, Srivastava and Jain (2011) stated that water and nutrient absorption processes are severely restricted, which can lead to reduced shoot growth. Chromium is competent of creating metabolic disorder during seed germination by disturbing the events related to the translation of food reservoirs into energy that is crucial for the subsequent successful emergence and establishment of seedlings. Nath *et al.* (2008) conducted an experiment in cowpea seeds combined with different concentrations of Cr6+, the activity of amylase enzyme and total sugar was strikingly decreased, resulting in dejection of germination features. Increased levels of Cr in different valence states were linked with a parallel decline in seed germination (Nagajyoti *et al*., 2010). Chromium involves efficiently and interferes with the absorption or accumulation of an extensive range of other metals which includes Fe, Mn, Ca, Mg, K, and P in both aerial and underground parts of plants, mostly leading to their reduced cellular concentration (Samantaray *et al.,* 1998). A research was done on the outcome of different trace metals on three *Veronica* species (Plantaginaceae) and proved a high optimistic relationship between Fe and Cr concentration in the tissues of the plant (Zivkovic *et al*., 2012).

Peralta *et al.* (2001) observed that the ability of a seed to germinate in a medium containing Cr would be investigative of its level of tolerance to this metal. Rout *et al*. (2000) found the seed germination was reduced with 20 ppm Cr high levels of the weed *Echinochloa colona*. Nearly 23% of the seeds ability of Lucerne was decreased by 40ppm of Cr (VI) (Peralta *et al.,* 2001). Zeid (2001) observed protease activity increases with the Cr treatment which directly contributes to the reduction in germination. Bishnoi *et al*. (1993) reported the more obvious results in isolated chloroplasts of Pisum sativum where the effect of Cr (VI) on PS I is greater than on PS II activity. Nevertheless, in entire plants, both the photosystems were overstressed.

There are three types of metabolic modifications in plants can be caused by chromium which includes alteration in the production of pigments (Boonyapookana *et al*., 2002), increased production of metabolites which may damage the plants (Shankar *et al*., 2003a) and alterations in the metabolic process to customize the production of new biochemically related metabolites (Schmfger, 2001). Figure 3 illustrates the negative influence of chromium on growth and development of plants.

4.3. Effects of Lead

Lead forms a range of complexes with soil apparatus and only a small amount of lead present as these complexes in the soil solution are available to the plants. As the element lack any specific essential function in plants, it is absorbed by them mainly through the roots and thereby enter the food chain. This occurs via the apoplastic pathway channels. After uptake, lead mainly accumulates in root cells, because of the blockage by casparian strips within the endodermis. Excessive lead accumulation in plant tissue impairs various morphological, physiological and biochemical functions in plants, either directly or indirectly and induces a range of deleterious effects (Pourrut *et al*., 2011). There is a remarkable decrease in total chlorophyll content in lead treated plants as compared to control throughout experimental period (Hamid *et al.,* 2010).

There is a decline of total protein content in *Phaseolus vulgaris* after one week treatment of lead is reported by Hamid *et al.* (2010). And this decrease was observed till the end of experimental period. The lead treatment 100 ppm showed much more toxic effect on total protein content. Pb at 50 and 100 mg kg^{-1} of soil level increased the amino acid content of cluster bean plant. In *Abelmoschus esculentus*, free amino acids, proline, catalase and peroxidase activity was increased with increasing concentration of lead acetate (Murugalakshmikumari and Ramasubramanian, 2014). *Brassica juncea* exhibited the proline content increased by Pb (1500 M) at the flowering stage (John *et al.,* 2009). Liu *et al.* (2010) stated that in wheat, the activity of catalase increased with increasing concentrations of lead on 21 days after sowing.

According to Pourrut *et al*. (2011), it causes phytotoxicity by changing cell membrane permeability, by reacting with active groups of different enzymes involved in plant metabolism and by reacting with the phosphate groups and by replacing significant ions. In addition, lead deeply inhibits seed germination, elongation of roots, seedling development and growth of plants, chlorophyll production and protein content. Lead has negative effects on plants primarily from the following factors such as deformation of chloroplast ultrastructure, stops the synthesis of enzymes of Calvin cycle, impaired uptake of essential elements, such as Mg and Fe and induced shortage of CO_2 resulting from closure of stomata. Under lead pressure, plants possess several defense strategies to deal which includes lesser uptake into the cell, sequestration of lead into vacuoles by complex formation, binding of lead by phytochelatins, amino acids etc. and production of osmolytes. Additionally, activation of various antioxidants to struggle increased production of lead-induced ROS constitutes a secondary defense system. Figure 4 represents the negative effects of lead in plant growth and development.

5. Future perspectives

A recent review of many specific studies addressed that plant interactions or co-exposure to metal/metalloid mixtures of cadmium, chromium and lead produced more severe effects at both comparatively high dose and low dose levels in a biomarker-specific approach. There is a lack of comprehensive study on the crop plants, especially millets which mostly grow on the waste lands and agricultural soils. Increased use of industrial effluents for irrigation, metal accumulation, translocation in soil and plant necessitated study needs much more attention. This important implication in the understanding of heavy metal contamination need to be understood through the food chain. Some of the studies of heavy metals accumulation on wheat and millet crops revealed that the accumulation of metal toxicity is more in the roots while other parts including grains contained low levels. Less accumulation of heavy metals in grains does not mean that they are completely safe for human consumption and feed for animals. Local people should be aware of administering untreated wastewater to crops and necessary steps to be taken in this direction to make sure that proper irrigation is carried out in agricultural fields, otherwise the results will be much more dangerous in the future. A promising biotechnological approach is needed on detoxification or remediation of heavy metal which is necessary for the protection and conservation of the environment. Furthermore, many research are needed to shift lab-to-land to provide realistic information about elemental defense in natural habitat.

CONCLUSION

The Literature review of the present research reports indicate that the presence of heavy metals especially cadmium, chromium and lead has adverse effects on plant growth and development. There is much more intensive research is needed for a better understanding of heavy metal toxicity on crop plants. The interrelationship between heavy metal stress and the growth and development of crop plants is a less explored research area. Much research is needed on this aspect in future and we are currently investigating on the interaction of heavy metal stress in millet crop growth and development.

As a conclusion, it is difficult to understand the adverse effect of heavy metal on the environmental aspect due to lack of insufficient information. Thus, the present review provides a pavement for future research and development for the assessment and treatment of emerging metal pollutants with various innovative and eco-friendly methods to improve the productivity of plants without any adverse effect in growth and development.

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CONFLICTS OF INTEREST

All authors have declared that they do not have any conflict of interest for publishing this research.

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