Effect of Heavy Metals on Plants: An Overview

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ABSTRACT

Wastes are the major source of soil pollution originates from mining, chemical, metal processing industries, and other allied industries. These wastes include varieties of chemicals like heavy metals, phenolic, organic, non-metals, etc. Heavy metals are the intrinsic component of the environment with essential and non essential both types. Soils polluted with heavy metals have become common due to increase in geologic and anthropogenic activities. It is the unplanned disposal of municipal waste, mining, use of extensive pesticides, insecticides, fungicides, and other agrochemicals uses were significant causes of environment pollution and causes of most concern. Heavy metals, such as cadmium, copper, lead, chromium, manganese, iron and mercury is major environmental pollutants, particularly in areas with high anthropogenic pressure. Heavy metal accumulation in soils is of concern in agricultural production due to the adverse effects on food safety, marketability and crop growth due to phytotoxicity, and environmental health of soil organisms. The influence of these heavy metals on plants and their metabolic activities caused by the geological and biological redistribution of heavy metals through pollution of the air, water and soil were briefly discussed in this article.

Keywords: Heavy metal, toxicity, effect on plants, heavy metal pollution and Soil pollution

1. INTRODUCTION

A heavy metal is toxic when relatively it is dense metal or metalloid that is noted for its potential toxicity, especially in environmental contexts. Heavy metal toxicity means excess of required concentration or it is unwanted which were found naturally on the earth, and become concentrated as a result of human caused activities, enter in plant, animal and human tissues via inhalation, diet and manual handling, and can bind to, and interfere with the functioning of vital cellular components. Heavy metals were significant environmental pollutants; their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons [1]. They are group of metals and metalloids with atomic density greater than 4 g/cm3, or 5 times or more, greater than water [2] including copper (Cu), manganese (Mn), lead (Pb), cadmium (Cd), nickel (Ni), cobalt (Co), iron (Fe), zinc (Zn), chromium (Cr), iron (Fe), arsenic (As), silver (Ag) and the platinum. Environmentally it is defined as total circumstances surrounding an organism or group of organisms especially, the combination of external physical conditions that affect and influence the growth, development and survival of the organisms [3]. They are largely found in dispersed form in rock formations. Increasing industrialization and urbanization had anthropogenic contribution of heavy metals in biosphere and had largest availability in soil and aquatic ecosystems and to a relatively smaller pro-portion in atmosphere as particulate or vapors. It toxicity in plants varies with plant species, specific metal, concentration, chemical form and soil composition and pH, as many heavy metals are considered to be essential for plant growth. Some of these heavy metals like Cu and Zn either serve as cofactor and activators of enzyme reactions [4].It exhibit metallic properties such as ductility, malleability, conductivity, cation stability and ligand specificity were characterized by relatively high density and high relative atomic weight with an atomic number greater than 20 [5]. eavy metals such as Co, Cu, Fe, Mn, Mo, Ni, V, and Zn are required in minute quantities by organisms, excessive amounts of these elements can become harmful to organisms. Heavy metals such as Pb, Cd, Hg, and as (a metalloid but generally referred to as a heavy metal) do not have any beneficial effect on organisms and are thus regarded as the “main threats” since they are very harmful to both plants and animals, pollutant in the environment air, water and soil, may be poisonous or toxic and will cause harm to living things. Metals accumulate in ecological food chain through uptake at primary producer level and then through consumption at consumer levels and plants roots are the primary contact site for heavy metal ions. Whereas, in aquatic systems plant body is exposed to these ions and heavy metals are absorbed directly to the leaves due to particles deposited on the foliar surfaces. This paper briefly describes the nature and properties of soils pollution with heavy metals and its effect on the plant growth were reviewed.

2. EFFECTS OF HEAVY METAL ON PLANTS

2.1 Nature of heavy metals

Heavy metals are natural components cannot be degraded or destroyed biologically. Life cann't develop and survive without the metal ions as life is as much inorganic as organic. Trace element to designate the elements which occur in small concentrations in natural biological systems concern over the deteriorating quality of the environment led to a trace element. The elementary constituents of plant, animal and human life may be classified as major and trace elements, the latter group comprising both essential and non-essential elements (including toxic elements).

2.2 Essential heavy metals

Some of heavy metals (Fe, Cu and Zn) are essential for plants and animals [6], their availability in medium varies, and metals such as Cu, Zn, Fe, Mn, Mo, Ni and Co are essential micronutrients [7], whose uptake in excess to the plant requirements result in toxic effects [8]. Range of a few important heavy metals in plants like As 0.02-7; Cd 0.1-2.4; Hg 0.005-0.02; Pb 1-13; Sb 0.02-0.06; Co 0,05-0.5; Cr 0.2-1; Cu 4.15; Fe 140; Mn 15-100; Mo 1-10; Ni 1; Sr 0.30 and Zn 8-100 in µg g^{-1} dry wt. on land plants [9].

2.2 Effect of heavy metals

The heavy metals available for plant uptake are those present as soluble components in the soil solution or those solubilized by root exudates [10]. Plants require certain heavy metals for their growth and upkeep, excessive amounts of these metals can become toxic to plants and ability of plants to accumulate essential metals equally enables them to acquire other nonessential metals [11]. As metals cannot be broken down, when concentrations within the plant exceed optimal levels, they adversely affect the plant both directly and indirectly and some of the direct toxic effects caused by high metal concentration include inhibition of cytoplasmic enzymes and damage to cell structures due to oxidative stress [12, 13]. Indirect toxic effect is the replacement of essential nutrients at cation exchange sites of plants [14]. The negative influence of heavy metals on the growth and activities of soil microorganisms also indirectly affect the growth of plants. Reduction in the number of beneficial soil microorganisms due to high metal concentration may lead to decrease in organic matter decomposition leading to a less fertility of soil. Enzyme activities are very much useful for plant metabolism, hampered due to heavy metal interference with activities of soil microorganisms. These toxic effects (both direct and indirect) lead to a decrease in plant growth which finally results in the death of plant [15].

The effect of heavy metal toxicity on the growth and development of plants differs according to the particular heavy metal for that process. Metals such as Pb, Cd, Hg, and As which do not play any beneficial role in plant growth, adverse effects have been recorded at very low concentrations of these metals in the growth medium. Kibra [16] noticed significant reduction in height of rice plants growing on the soil contaminated with 1 mg Hg/kg with reduction in tiller and panicle formation. For Cd toxicity which reduces the shoot and root growth in wheat plants when Cd as low as 5 mg/L in the soil[17]. Most of the reduction in growth parameters of plants growing on polluted soils can be attributed to reduced photosynthetic activities, plant mineral nutrition, and reduced activity of some enzymes [18].

Like every living organisms, plants are often sensitive both to the deficiency and to the excess availability of some heavy metal ions as essential micronutrient, while the same at higher concentrations and even more ions such as Cd, Hg, as are strongly poisonous to the metabolic activities. Research has been conducted throughout the world to determine the effects of toxic heavy metals on plants [54]. Contamination of agricultural soil by heavy metals has become a critical environmental concern due to their potential adverse ecological effects. Such toxic elements are considered as soil pollutants due to their widespread occurrence and their acute and chronic toxic effect on plants grown of such soils.

2.2.1 Effects of copper on plants

Copper is an essential metal for normal plant growth and development, although it is also potentially toxic. Copper (Cu) is considered as a micronutrient for plants [55] and plays important role in CO_2 assimilation and ATP synthesis [31]. Study conducted at Malanzkhand Copper Project (MCP) of Hindustan Copper Limited (HCL) at Malanzkhand, district Balaghat, M.P in which it was found that copper dust had adverse effect on various photosynthesis pigmentation secretions in many trees species leaves (27, 32). Cu is also an essential component of various proteins like plastocyanin of photosynthetic system and cytochrome oxidase of respiratory electron transport chain [56]. But enhanced industrial and mining activities have contributed to the increasing occurrence of Cu in ecosystems. Cu is also added to soils from different human activities including mining and smelting of Cu containing ores.

Mining activities generate a large amount of waste rocks and tailings, which get deposited at the surface. Excess of Cu in soil plays a cytotoxic role, induces stress and causes injury to plants. This leads to plant growth retardation and leaf chlorosis [30, 57]. Exposure of plants to excess Cu generates oxidative stress and ROS [58]. Oxidative stress causes disturbance of metabolic pathways and damage to macromolecules [27, 59]. Copper reduces the root growth in rhodes grass (*Chloris gayana*) [26, 27]. In black bindweed (P*olygonum convolvulus*) the plant mortality, biomass and seed production is reduced due to copper toxicity [28, 31]. In bean (*Phaseolus vulgaris*) accumulation of Cu in plant roots and root malformation and reduction seen [29, 30].

2.2.2 Effect of zinc on plants

The function of zinc is to help a plant to produce chlorophyll. Leaves get discolor when the soil is deficient in zinc and plant growth is stunted [136]. Zinc deficiency causes leaf discoloration called chlorosis tissue of the veins to turn yellow. Chlorosis by zinc deficiency usually affects the base of the leaf near the stem. Chlorosis appears on the lower leaves first, and then gradually moves up to the plant. In severe cases, the upper leaves become chlorotic and the lower leaves turn brown or purple and die. When plants show symptoms this severe, it's best to pull them up and treat the soil before replanting. Zinc (Zn) is an essential micronutrient that affects several metabolic processes of plants [60] and has a long biological half life. The phytotoxicity of Zn and Cd is indicated by decrease in growth and development, metabolism and an induction of oxidative damage in various plant species such as Phaseolus vulgaris [61] and Brassica juncea [62]. Cd and Zn have reported to cause alternation in catalytic efficiency of enzymes in Phaseolus vulgaris [63] and pea plants [64]. Concentrations of Zn found in contaminated soils frequently exceed to those required as nutrients and may cause phytotoxicity. Zn concentrations in the range of 150–300 mg/kg have been measured in polluted soils [65]. High levels of Zn in soil inhibit many plant metabolic functions; result in retarded growth and cause senescence. Zinc toxicity in plants limited the growth of both root and shoot [66].

Zinc toxicity also causes chlorosis in the younger leaves, which can extend to older leaves after prolonged exposure to high soil Zn levels [67]. The chlorosis may arise partly from an induced iron (Fe) deficiency as hydrated Zn^{+2} and Fe^{+2} ions have similar radii [68]. Excess Zn can also give rise to manganese (Mn) and copper (Cu) deficiencies in plant shoots. Such deficiencies have been ascribed to a hindered transfer of these micronutrients from root to shoot. This hindrance is based on the fact that the Fe and Mn concentrations in plants grown in Zn rich media are greater in the root than in the shoot [67]. Another typical effect of Zn toxicity is the appearance of a purplish red color in leaves, which is ascribed to phosphorus (P) deficiency [69]. Zinc in excess reduces the germination, chlorophyll, carotenoid, sugar, amino acid and growth of cluster beans (Cyamopsis tetragonoloba) [19]. Whereas, in pea (Pisum sativum) reduces chlorophyll, photosynthesis and plant growth [20, 31]. In rye grass (Lolium perenne) it reduces the growth, nutrient content and photosynthetic energy conversion [21].

2.2.3 Effects of cadmium on plants

The permissible limit of cadmium (Cd) in agricultural soil is 100 mg/kg soil [70]. Plants grown in soil containing high levels of Cd show visible symptoms of injury reflected in terms of chlorosis, growth inhibition, browning of root tips and finally death [71,72,73]. The inhibition of root Fe (III) reductase induced by Cd led to Fe (II) deficiency, and it seriously affected photosynthesis. In general, Cd has been shown to interfere with the uptake, transport and use of several elements (Ca, Mg, P and K) and water by plants [74]. Cd also reduced the absorption of nitrate and its transport from roots to shoots, by inhibiting the nitrate reductase activity in the shoots [75]. Appreciable inhibition of the nitrate reductase activity was also found in plants of Silene cucubalus [76]. Nitrogen fixation and primary ammonia assimilation decreased in nodules of soybean plants during Cd treatments [77]. Metal toxicity can affect the plasma membrane permeability, causing a reduction in water content; in particular, Cd has been reported to interact with the water balance [78]. Cadmium treatments have been shown to reduce ATPase activity of the plasma membrane fraction of wheat and sunflower roots [79]. Cadmium produces alterations in the functionality of membranes by inducing lipid peroxidation [79] and disturbances in chloroplast metabolism by inhibiting chlorophyll biosynthesis and reducing the activity of enzymes involved in CO_2 fixation [80].

In wheat (Triticum sp.) excessive of cadmium reduces the seed germination; decrease in plant nutrient content; reduced shoot and root length [17, 47]. Whereas in garlic (Allium sativum) Cd accumulation reduced shoot growth [48]. Lastly in Maize (Zea mays) it reduces shoot growth and inhibition of root growth [49].

2.2.4 Effects of mercury on plants

Mercury is not essential for plant growth. Contamination of soils by Hg is often due to the addition of this heavy metal as part of fertilizers, lime, sludges, and manures. The dynamics between the amount of Hg that exist in the soil and its uptake by plants is not linear and depends on several variables (e.g., cation-exchange capacity, soil pH, soil aeration, and plant species). The large input of mercury (Hg) into the arable lands has resulted in the widespread occurrence of mercury contamination in the entire food chain. Hg is a unique metal due to its existence in different forms e.g., HgS, Hg^{+2}, Hg^{o} and methyl-Hg. However, in agricultural soil, ionic form (Hg^{+2}) is predominant [81]. Hg released to the soil mainly remains in solid phase through adsorption onto sulfides, clay particles and organic matters. Increasing evidence has shown that Hg^{+2} can readily accumulate in higher and aquatic plants [82, 83]. High level of Hg^{+2} is strongly phytotoxic to plant cells. Toxic level of Hg^{+2} can induce visible injuries and physiological disorders in plants [84]. For example, Hg^{+2} can bind to water channel proteins, thus inducing leaf stomata to close and physical obstruction of water flow in plants [85]. High level of Hg^{+2} interfere the mitochondrial activity and induce oxidative stress by triggering the generation of ROS. This leads to the disruption of bio-membrane lipids and cellular metabolism in plants [86].

In rice (*Oryza sativa*) excess of mercury decreases plant height, reduces tiller and panicle formation, yield reduction and increase of its bioaccumulation in shoot and root of seedling [16, 42]. Further, in tomato (*Lycopersicon* *esculentum*) show reduction in germination percentage, reduced plant height; reduction in flowering and fruit weight and finally resultant chlorosis appears on the whole plant [43].

2.2.5 Effects of chromium on plants

Chromium is known to be a toxic metal that can cause serve damage to plants and animals. Chromium induced oxidative stress involves induction of lipid peroxidation in plants that causes severe damage to cell membranes. Oxidative stress induced by chromium initiates the degradation of photosynthetic pigments causing decline in growth. High chromium concentration can disturb the chloroplast ultra structure there by disturbing the photosynthetic process. Since seed germination is the first physiological process affected by Cr, the ability of a seed to germinate in a medium containing Cr would be indicative of its level of tolerance to this metal [87]. Seed germination of the weed Echinochloa colona was reduced to 25% with 200 µM Cr [88]. High levels (500 ppm) of hexavalent Cr in soil reduced germination up to 48% in the bush bean Phaseolus vulgaris [89]. Peralta [87] found that 40 ppm of Cr (VI) reduced by 23% the ability of seeds of Lucerne (Medicago sativa) to germinate and grow in the contaminated medium [90]. Reductions of 32–57% in sugarcane bud germination were observed with 20 and 80 ppm Cr, respectively [91]. The reduced germination of seeds under Cr stress could be a depressive effect of Cr on the activity of amylases and on the sub sequent transport of sugars to the embryo axes. Protease activity, on the other hand, increases with the Cr treatment, which could also contribute to the reduction in germination of Cr treated seeds [92]. Decrease in root growth is a well documented effect due to heavy metals in trees and crops [93]. Prasad [94] reported that the order of metal toxicity to new root primordia in Salix viminalis is Cd > Cr > Pb, whereas root length was more affected by Cr than by other heavy metals studied. Chromium stress is one of the important factors that affect photosynthesis in terms of CO_2 fixation, electron transport, photophosphorylation and enzyme activities [95].

In higher plants and trees, the effect of Cr on photosynthesis is well documented [96]. However, it is not well understood to what extent Cr induced inhibition of photosynthesis is due to disorganization of chloroplasts' ultra structure [97], inhibition of electron transport or the influence of Cr on the enzymes of the Calvin cycle. Chromate is used as a Hill reagent by isolated chloroplast [98]. Chromium stress can induce three possible types of metabolic modification in plants: (i) alteration in the production of pigments, which are involved in the life sustenance of plants (e.g., chlorophyll, anthocyanin) [99] (ii) increased production of metabolites (e.g., glutathione, ascorbic acid) as a direct response to Cr stress, which may cause damage to the plants [100] and (iii) alterations in the metabolic pool to channelise the production of new biochemically related metabolites, which may confer resistance or tolerance to Cr stress (e.g., phytochelatins, histidine) [101]. Induction and activation of superoxide dismutase (SOD) and of antioxidant catalase are some of the major metal detoxification mechanisms in plants [102]. In tomato (Lycopersicon esculentum) chromium toxicity resultant decrease in plant nutrient acquisition [32,33]. Wherein, onion (Allium cepa) shows the inhibition of germination process and reduction of plant biomass[34]. Moreover, in wheat (Triticum sp.) Reduction of shoot and root growth were noticed [35, 36].

2.2.6 Effects of lead on plants

Plants on land tend to absorb lead from the soil and retain most of this in their roots. There is some evidence that plant foliage may also take up lead (and it is possible that this lead is moved to other parts of the plant). The uptake of lead by the roots of the plant may be reduced with the application of calcium and phosphorus to the soil. Lead (Pb) is one of the ubiquitously distributed most abundant toxic elements in the soil. It exerts adverse effect on morphology, growth and photosynthetic processes of plants. Lead is known to inhibit seed germination of Spartiana alterniflora, Pinus helipensis [103]. Inhibition of germination may result from the interference of lead with important enzymes. Mukherji and Maitra [104] observed 60 µM lead acetate inhibited protease and amylase by about 50% in rice endosperm. Early seedling growth was also inhibited by lead in soya bean, rice [105], maize [106], barley, tomato and certain legumes [107]. Lead also inhibited root and stem elongation and leaf expansion in Allium species barley [108] and Raphanus sativas. The degree to which root elongation is inhibited depends upon the concentration of lead and ionic composition and pH of the medium [109]. Concentration dependent inhibition of root growth has been observed in Sesamum indicum [110]. A high lead level in soil induces abnormal morphology in many plant species. For example, lead causes irregular radial thickening in pea roots, cell walls of the endodermis and lignification of cortical parenchyma [111]. Lead also induces proliferation effects on the repair process of vascular plants [112]. Lead administrated to potted sugar beet plants at rates of 100–200 ppm caused chlorosis and growth reduction [113]. High Pb concentration also induces oxidative stress by increasing the production of ROS in plants [114].

In maize (Zea mays) reduction in germination percentage; suppressed growth; reduced plant biomass; decrease in plant protein content has been noticed [54]. Whereas in Portia tree (Thespesia populnea) Reduction in number of leaves and leaf area; reduced plant height[55]; decrease in plant biomass and in Oat (Avena sativa) Inhibition of enzyme activity which affected CO_2 fixation[56].

2.2.7 Effects of Cobalt on plants

Cobalt, a transition element, is an essential component of several enzymes and co-enzymes. It has been shown to affect growth and metabolism of plants, in different degrees, depending on the concentration and status of cobalt in rhizosphere and soil. Cobalt interacts with other elements to form complexes. The cytotoxic and phytotoxic activities of cobalt and its compounds depend on the physicochemical properties of these complexes, including their electronic structure, ion parameters (charge-size relations) and coordination. The uptake and distribution of Co in plants is species dependent and controlled by different mechanisms [115, 116]. Cobalt (Co) naturally occurs in the earth's crust as cobaltite [CoAsS], erythrite [$Co_3(AsO_4)_2$] and smaltite [$CoAs_2$]. Plants can accumulate small amount of Co from the soil. Very little information is available regarding the phytotoxic effect of excess Co. Phytotoxicity study of Co in barley (Hordeum vulgare L.), oilseed rape (Brassica napus L.) and tomato (Lycopersicon esculentum L.) has recently shown the adverse effect on shoot growth and biomass [117]. In addition to biomass, excess of Co restricted the concentration of Fe, chlorophyll, protein and catalase activity in leaves of cauliflower. Further, high level of Co also affected the translocation of P, S, Mn, Zn and Cu from roots to tops in cauliflower. In contrast to excess Cu or Cr, Co significantly decreased water potential and transpiration rate.

In raddish (Raphanus sativus) Reduction in shoot length, root length, and total leaf area; decrease in chlorophyll content; reduction in plant nutrient content and antioxidant enzyme activity; decrease in plant sugar, amino acid, and protein content has been noticed [44]. Mung bean (Vigna radiata) reduction in antioxidant enzyme activities; decrease in plant sugar, amino acid, and protein content[45]. Tomato (Lycopersicon esculentum) Reduction in plant nutrient content [46].

2.2.8 Effects of nickel on plants

Nickel is an essential nutrient for plants. However, the amount of Ni required for normal growth of plants is very low. Hence, with the level of Ni pollution in the environment increasing, it is essential to understand the functional roles and toxic effects of Ni in plants. Ni^{+2} concentration in polluted soil may range from 20 to 30 fold (200–26,000 mg/kg) higher than the overall range (10–1,000 mg/kg) found in natural soil [118]. However, Ni^{+2} concentration is increasing in certain areas by human activities such as mining works, emission of smelters, burning of coal and oil, sewage, phosphate fertilizers and pesticides [119]. Excess of Ni^{+2} in soil causes various physiological alterations and diverse toxicity symptoms such as chlorosis and necrosis in different plant species, including rice [120, 121, 122]. Plants grown in high Ni^{+2} containing soil showed impairment of nutrient balance and resulted in disorder of cell membrane functions. Thus, Ni^{+2} affected the lipid composition and H-ATPase activity of the plasma membrane as reported in Oryza sativa shoots [123].Other symptoms observed in Ni^{+2} treated plants were related with changes in water balance. High uptake of Ni^{+2} induced a decline in water content of dicot and monocot plant species. The decrease in water uptake is used as an indicator of the progression of Ni^{+2} toxicity in plants [124, 125].

In pigeon pea (Cajanus cajan) nickel decreases chlorophyll content and stomatal conductance; decrease enzyme activity which affected Calvin cycle and CO2 fixation[37]. Due to nickel Rye grass (Lolium perenne) reduction in plant nutrient acquisition; decrease in shoot yield; chlorosis[38]. In wheat (Triticum sp.) reduction in plant nutrient acquisition [39, 40]. Finall, in Rice (Oryza sativa) Inhibition of root growth[41] due to this heavy metals.

2.2.9 Effects of iron on plant

Iron is mainly involved in the process of plant photosynthesis. The micronutrient's availability to plant roots depends on the pH level of the soil with iron more readily available in soil with a low pH. Iron and manganese both play an important role in plant growth and development, but often compete for absorption, as an abundance of one of these micronutrients makes the other less available to plant roots. Iron is a major constituent of the cell redox systems such as heme proteins including cytochromes, catalase, peroxidase and leghemoglobin and iron sulfur proteins including ferredoxin, acontiase and superoxide disumutase (SOD) [126]. Iron as an essential element for all plants has many important biological roles in the processes as diverse as photosynthesis, chloroplast development and chlorophyll biosynthesis. Although most mineral soils are rich in iron, the expression of iron toxicity symptoms in leaf tissues occurs only under flooded conditions, which involves the micro-bial reduction of insoluble Fe^{+3} insoluble Fe^{+2} [127]. Iron toxicity in tobacco, canola, soybean and Hydrilla verticillata are accompanied with reduction of plant photosynthesis and yield and the increase in oxidative stress and ascorbate peroxidise activity [128]. The appearance of iron toxicity in plants is related to high Fe^{+2} uptakes by roots and its transportation to leaves and via transpiration stream. The Fe^{+2} excess cause free radical production that impairs cellular structure irreversibly and damages membranes, DNA and proteins [129]. Iron toxicity is not common, but some plants do secrete acids from the roots, which lowers soil pH. These plants can take up too much iron, leading to toxicity.

2.2.10 Effects of manganese on plants

Manganese (Mn) is an essential plant mineral nutrient, playing a key role in several physiological processes, particularly photosynthesis. Manganese deficiency is a widespread problem, most often occurring in sandy soils, organic soils with a pH above 6 and heavily weathered, tropical soils. Mn is readily transported from root to shoot through the transpiration stream, but not readily remobilized through phloem to other organs after reaching the leaves [130]. Necrotic brown spotting on leaves, petioles and stems is a common symptom of Mn toxicity [131]. This spotting starts on the lower leaves and progresses with time toward the upper leaves [132]. With time, the speckles can increase in both number and size resulting in necrotic lesions, leaf browning and death [133]. Another common symptom is known as ''crinkle leaf'', and it occurs in the youngest leaf, stem and petiole tissue. It is also associated with chlorosis and browning of these tissues [131, 133]. Manganese toxicity in some species starts with chlorosis of older leaves moving toward the younger leaves with time. This symptom starts at the leaf margins progressing to the interveinal areas and if the toxicity is acute, the symptom progresses to marginal and interveinal necrosis of leaves [134]. Excess Mn is reported to inhibit synthesis of chlorophyll by blocking a Fe concerning process [135]. Manganese toxicity is a relatively common problem compared to other micronutrient toxicity. It normally is associated with soils of pH 5.5 or lower, but can occur whenever the soil pH is below 6.0 symptoms include chlorosis and necrotic lesions on old leaves, dark brown or red necrotic spots, accumulation of small particles of MnO_2 in epidermal cells of leaves or stems, often referred to as "measles", drying leaf tips, and stunted roots. In the broad bean (Vicia faba) Mn accumulation in shoot and root; reduction in shoot and root length; chlorosis [22]. Otherside in spearmint (Mentha spicata) Mn decrease the chlorophyll a and carotenoid content; increase accumulation of Mn in plant roots [23]. Moreover, Mn in pea (Pisum sativum) reduces chlorophylls a and b content; reduction in relative growth rate; reduced photosynthetic O2 evolution activity and photosystem II activity [24]. However, in tomato (Lycopersicon esculentum) Mn slower plant growth; decrease in chlorophyll concentration [25].

2.2.11 Effects of arsenic on plants

In tomato (Lycopersicon esculentum) arsenic reduces fruit yield, decreases the leaf fresh weight[50]. Whereas, in canola (Brassica napus) arsenic causes stunted growth, chlorosis and wilting [51]. Further, arsenic in rice (Oryza sativa) reduces seed germination, decrease in seedling height, reduces leaf area and dry matter production [52,53].

3. CONCLUSION

Plants grow on heavy metal polluted soils resultant in reduction in growth due to changes in their physiological and biochemical activities especially true when the heavy metal involved does not play any beneficial role towards the growth and development of plants. Thus, it is evident from the several research findings that judicious use and presence of heavy metals having toxic effects on plants, animals and many living organisms after certain limits. Therefore, indeed to intensify the research for better understanding of heavy metal toxicity on plants and allied areas to maintain the ecological harmony of our planet. There are two aspects on the interaction of plants and heavy metals, one hand, heavy metals show negative effects on plants and other hand, plants have their own resistance mechanisms against toxic effects and for detoxifying heavy metal pollution. Our review showed that both growth and photosynthetic pigments are affected by the presence of heavy metals. The toxicity of heavy metals which is caused by their accumulation in soil can be removed by using hyperaccumulator plant through bioremediation/phytoremediation process effectively used for the treatment of heavy metal polluted soil. Plants employ different mechanisms in the remediation of heavy metal polluted soils and phytoextraction is the most common method of phytoremediation used for treatment of heavy metal polluted soils which ensures the complete removal of the pollutant.

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