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A CRITICAL REVIEW ON THE EFFECT AND TOXICITY OF CADMIUM MEDIATED STRESS IN PLANTS

Prity Basak and Bhaskar Choudhury [*]

Guru Nanak Institute of Pharmaceutical Science and Technology, Kolkata - 700114, West Bengal, India.

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Correspondence to Author:
Dr. Bhaskar Choudhury

Associate Professor,
Guru Nanak Institute of Pharmaceutical Science and Technology, Kolkata - 700114, West Bengal, India.

E-mail: bhaskar.choudhury@gnipst.ac.in

ABSTRACT: Cadmium (Cd) is one of the non-essential and highly toxic environmental pollutants. It causes serious environmental and agricultural problems. It ranks seventh on the list of the twenty most toxic metals. Dietary cadmium intake is much higher than the upper limit reported by FAO/WHO. Sources of environmental Cd contamination, soil factors affecting Cd uptake, Cd dynamics in the soil rhizosphere, uptake mechanisms, Cd transport and toxicity in plants. In crops, Cd toxicity reduces nutrient and water uptake and transport, increases oxidative damage, disrupts plant metabolism, and disrupts plant morphology and physiology. Factors effecting the uptake and translocation of Cd in plants are elaborated to understand the mechanism that contributes to its accumulation. Cadmium disturbs the function of chloroplasts by accumulating to higher levels in aerial parts. It inhibits the enzymes needed for chlorophyll biosynthesis as well as enzymes for carbon dioxide fixation Ribulose-1, 5-biphosphate carboxylase (RUBPCase) and phosphoenol pyruvate carboxylase (PEPCase). Using molecular techniques, including identification of QTLs, CRISPR/Cas9, and functional genomics, to amplify the adverse effects of Cd on plants is of great utility. This review also discussed on the phytoremediation techniques like phyto extraction, phyto stimulation, phyto stabilization, phytovolatization and rhizofiltration to combat against cadmium toxicity.

INTRODUCTION: Cadmium (Cd) is a non-essential element that can be accumulated by plants. It is highly toxic and is taken up by plants. It is toxic at relatively low concentrations. It is a non-essential element with no biological role. It affects plants at the morphological, physiological, biochemical, and molecular levels. Cadmium (Cd) may result in plant physiological disorders and increased oxidative stress (overproduction of reactive oxygen species [ROS]). Cadmium (Cd) tolerance and adaptation are regulated by different changes at the molecular level.

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Some genes were found to be expressed under cadmium stress [1]. It reduces the root and shoots length and photosynthetic pigments in crop species. It can reduce enzyme activity in different parts of plants. It is used to decrease cadmium bioavailability in soil and its plant concentration. Zinc (Zn) could be used to relieve Cadmium (Cd) stress in numerous species of plants. Cadmium (Cd) toxicity is under Zn deficient condition [2].

Chlorosis and stunted growth are predominant symptoms in plants caused by the toxicity of Cadmium. Cadmium (Cd) induces osmotic stress in plants by minimizing stomatal conductance, leaf water content, and transpiration. Cadmium (Cd) mobilization into the root cell of PM is the first barrier encountered by Cadmium during its plant transfer [3]. Its role in the soil rhizosphere is limited [4]. Early changes in grapevine roots induced by cadmium. Because it causes inhibition of carbohydrate hydrolysis and translocation of hydrolyzed sugars, and this results in a reduction in seedling growth [5]. It is a highly noxious HM that is deleterious for the biological system through its accumulation and uptake in phototrophs [6, 7]. Phytoremediation is a cost-effective technique for remediation. Its uptake and accumulation of cadmium inside its shoots, roots and leaves takes a long time to provide results [8]. High cadmium content is very harmful and affects on uptake, photosynthesis, and transportation of mineral elements. Cadmium disrupts the ion's homeostasis by inhibiting the absorption of ions and magnesium affects the metabolism of nitrogen and reducing the uptake of water and minerals. It is the toxic contaminants that control its mobility in paddy soils. Most of the food chain is contaminated by cadmium and it possibly comes from cereal. It has some health hazards such as lung edema, hypertension, skeletal variation, liver damage, and *Itai Itai* diseases [9]. Cadmium retards leaf photosynthesis which affects rice growth leaf size, and plant growth development. It is transformed from fixed to mobile form, which increases its bioavailability for the uptake of plants [10] **Fig. 1.**

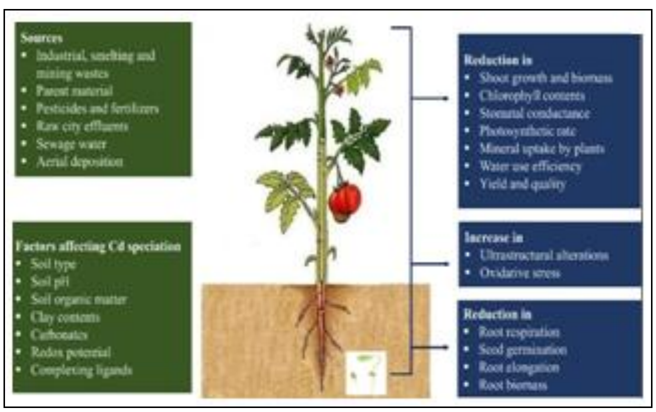

FIG. 1: RECENT DEVELOPMENTS IN THE EFFECTS AND STRATEGIES FOR REMEDIATION OF CADMIUM TOXICITY IN PLANTS [7]

Factors Affecting Cadmium Dynamics in Soil: Some factors like soil pH, redox potential, Organic matter, soil microorganisms, plant age, plant genotypes, micro and macronutrients, cation exchange capacity, and root exudates influenced the bioavailability of Cadmium. Soil pH decreases the availability of Cadmium increases. Soil pH is one of the factors that regulate the extractability of cadmium in soils. Cadmium exists in various forms at soil pH levels. In soil solution, cadmium solubility is affected by acidic soil conditions. For solubility in soil, pH 6 acts as a threshold point because it forms organic matter. It increased the dissolvability of Cd^{2+} in soil and Arranged for higher uptake by rice plants [11]. Soil influence cation exchange capacity for the bioavailability of cadmium. Cadmium if present in alkaline solutions they become less bioavailable. The bioavailability of cadmium depends on SOM concentration and chemical forms. SOM influences cadmium binding and its acclimatization. SOM causes more sorption potential than 30 times more than mineral oil [12]. Biochar reduced cadmium stress by reducing its bioavailability [13]. Cadmium accumulates in plants that depend on genotype and it increases tolerance to cadmium through a dilution effect. Organic matter affects the availability of cadmium in soil, it can retain metal contents [14, 15]. Organic amendments reduce the availability of cadmium to plants in highly cadmium polluted soils. Soil microbial activity enhances the availability of cadmium through organic acid secretion and solubilization of cadmium-bearing minerals. PGPRs (Plant Growth Promoting Rhizobacteria) play an important role in enhancing the bioavailability of cadmium[16, 17].

Micrococcus sp. TISTR2221 uptakes cadmium in the root and stem parts of the plant under cadmium stress. It reduces the toxicity of cadmium in plants and microbes. Cadmium phyto availability was found by soil bioaugmentation. Root exudates secondary products that are produced during photosynthesis and released into the soil through root system [7, 18, 19].

Factors Effecting on Plant Growth and Germination: Cadmium influences agricultural soils. Cadmium compounds are water soluble but cadmium solubility is definite by cadmium carbonate ($CdCO_3$). Cadmium availability is related to others, such as the capacity of exchange and cations concentration. It is an organically bound fraction that reduces uptake or bioavailability. A lower amount of Cd is found in contaminated soil. The capacity of cation exchange affects cadmium mobility in soil [20]. Cadmium is reported to affect plant growth due to its non-metabolic nature and extensive biological half-life. It's accumulation in plants reflects phytotoxic features, water and oxidative stress, and metabolism [21]. Cadmium consequences on seedling vigor index, germination index, and earlier plant growth. Cadmium-induced seed imbibitions is essential for the hydration of enzymes that are involved in physiological and biochemical activities [22, 23]. In germination high cadmium concentration inhibit hydrolysis of reserved sugars and translocation from the endosperm that grows the embryonic axis its contrary effects on hydrolyzing enzymes that's are Acid Phosphatase (ACPs) and α amylase. Cadmium stress decreases radical formation. Cellular osmoregulation is disrupted and degraded the proteolytic activities, inhibition of seed germination, and the development of seedlings [5].

In germination and seedling growth, Cd contamination causes plant growth deformities due to biochemical and molecular alterations and affects the morphological and physiological parameters [1]. Cadmium-induced abnormalities of general growth and biomass are linked to metabolic changes in plants. It inhibited assimilation which reduces protein and carbohydrate contents. Cadmium stress assimilated mitotic index and micronucleus formation, cell wall lignifications, DNA damage, and growth deformation including chlorosis, necrosis, rigid and mucilaginous roots, rolling of leaves, and stunted growth. Toxic effects on germination and growth are dependent on Cd concentration and differ from species to species and plant growth concentration [24].

Impact of Cadmium Toxicity on Plants: Seed germination is the most predominant activity in the lifecycle of the plants which regulated by the phytohormones like Auxin, Gibberellin, and Abscisic Acid [22, 25]. Cadmium reduces the germination of lettuce, sugar beet, and soybean seedlings. Cadmium-calmodulin binding sites between Ca and Cd ions existed in radish [22]. In the early stage of seed germination, the relationship between Calmodium and Cadmium plays a role in metabolic activation. Cadmium shows the oxidative stress which substantially higher Cd concentration, but the plants don't display signs of visual stress [26]. Cadmium is an oxidative stress inducer that elevated levels of ROS [27]. Cadmium is a non-essential element for plants and induces toxicity and inhibits many species of plants. The roots become necrotic, and mucilaginous, and decompose after long-term Cd exposure reducing due to the elongation of plants' roots and shoots. It cause's chlorosis [13]. It inhibits the formation of lateral roots and causes the main root to a rigid and brown. The increase in the size of cortical tissues and parenchymal cells that play a role in the resistance of plants to solute flow and cause water can increase in the root diameter under Cadmium stress [25]. Cd stress may be attributed to reducing the uptake of water and nutrient, photosynthesis, antioxidant activity, and assimilation of carbon and nitrogen [28, 29]. A high concentration of cadmium has minimized cell and plant growth of chickpeas, lentils, wheat, alfalfa, and soybeans [13, 23, 30].

Cadmium causes oxidative stress to plants; it inhibits the photo-activation of PSII due to the inhibition of electron transfer [6]. Cadmium contributes to the production of ROS through disruption in the chloroplasts of leaves. It stimulates ROS development in the mitochondrial electron transfer chain. The generation of ROS in plant cells is fast-acting. In plants, ROS damage includes peroxidation of proteins and lipids and they also damage DNA [31]. Cadmium damage nucleic acids and cell membranes, synthesis of protein to decrease, and photosynthetic protein damage influences the growth of organism [14].

The formation of free radicals increases the activities of various enzymes including peroxidase (POD), Ascorbate peroxidase (APX), Catalase (CAT), and Superoxide Dismutase (SOD) Cd causing overproduction of ROS such as H_2O_2, O_2, and OH^- in the cells. High levels of Cd induce antioxidant enzymes (APX, CAT, SOD, and Glutathione Reductase) in *Brassica juncea.* When seedlings were exposed. Cd shows an increase of APX, GR, SOD, MDHAR (monodehydroascorbate reductase), and GPX (Glutathione Reductase) activities in compared with the control seedlings, DHAR, GST, and CAT activities decrease. An increase of peroxidase and superoxide dismutase has been reported **Table 1.**

Cadmium has interacted with the storage and utilization of numerous elements and the uptake of water by plants. Cadmium toxicity minimizes Ca, Mg, N, and P contents in roots and shoots of alfalfa [23]. Cadmium and other toxic metals inhibit the transportation of micro and macronutrients in plants. Cadmium inhibits the chelation cycle of iron and the injection of iron into the xylem of roots.

Direct impacts lower the solubility of Cd in soil by absorption and precipitation it has membrane transporters and accumulation of cadmium in vegetative parts to prevent its sequestration in seeds and edible components. Indirect impacts involve the dilution of cadmium ions by enhancing plant productivity, biomass and physiological stress.

TABLE 1: ROLES OF ANTIOXIDANT ENZYMES [7, 43]

Antioxidant enzymes	Plant species	Effects on plants
GPOX, SOD, CAT	*Oryza sativa* (Rice)	Seedling growth improved against stress by MDA (malondialdehyde) in plants
SOD, CAT, POD	*Triticum aestivum* (Wheat)	Improved plant growth, seed germination, photosynthetic activity and soluble sugar contents in plants
SOD, POD, CAT	*Medicago sativa* (Alfalfa)	Improved plant growth and enhance proline and protein contents in plants
SOD, GR, CAT	*Saccharum officinarum* (Sugarcane)	Improved the photosystem II and photosynthesis activity
GPOX, SOD, APOX, CAT	*Pisum sativum* (Pea)	Enhance gene expressions against cadmium stress, cadmium tolerance and antioxidant activity
CAT APOX, SOD	*Glycine max* (Soybean)	Minimized thiobarbituric acid contents in plants and improved nitrogenase activity in plants

Photosynthetic Effect on Plants: Cadmium (Cd) causes negative effects on photosynthetic activities and it reduces the pigments of photosynthesis in crop plants [32]. A relationship between inhibition and transpiration of photosynthesis were also recorded in cereal crops, oilseed, and legumes indicating that Cd accumulation in leaves inhibits the stomata closing and opening [6, 18, 30]. Cadmium toxicity injures the light-harvesting complex and photosystems I and II. Cadmium-induced inhibition of iron affects the photosynthesis process. The interaction between Cd and chlorophyll minimizes the density of chloroplast and it leads to chlorosis. The decrease in chlorophyll is caused by Cd. It is more active on the surface of leaves than mesophyll cells. Cadmium toxicity causes a reduction in cell size and stomatal density in the epidermis of leaves. It interacts with the cells and chloroplasts in plants [13].

During photosynthesis, RUBPCase and PEPcase enzymes are vital for carbon fixation, and they are efficient for photosynthesis in plants. Cadmium ion decreases the RUBPCase activity which is an essential cofactor in the carboxylation reaction, and it changes the activity of the oxygenation reaction. Cadmium minimizes gas exchange parameters that damage chloroplast structure and photosynthetic pigments [26].

Effects on proteins and Amino Acids Contents: The proteomics approach is used in plants that are effective for Cd stress tolerance. Heat shock proteins have been stressed in the eukaryotic cell [33]. HSP71 and PrP4A have been detected to protect cells from damage caused by Cadmium toxicity. HSP71 and PrP4A proteins are enhanced in leaves. The higher concentration of Cadmium caused a change in 41 polypeptides [4]. Symptoms of cadmium toxicity in plants: The visual and non-visual symptoms have been observed in cadmium toxicity. The cadmium toxicity visual symptoms are chlorosis (colour discoloration), necrosis, stunted growth, photosynthesis rate, biomass reduction, wilting, and respiration inhibition reduction of biomass and changes in mineral composition. The symptoms depend on the concentration of cadmium absorbed.

Chlorosis and Necrosis: Chlorosis describes the loss of natural green pigments of plant leaves. It is important to produce chlorophyll pigments. Chlorophyll is important for the green color of leaves. As a result, insufficient chlorophyll in plants lights greenish, white-yellowish, or yellowish leaves. It causes insufficient light exposure. The bioavailability of cadmium contributes to its hyperaccumulation movement in plants. The symptoms of chlorosis are caused by cadmium. It was determined by the decrease in essential nutrients. The symptoms have been identified in some plant species including pea, rice, and oilseed rape which is grown in the soil and contaminated with cadmium [29, 34]. Necrosis is a symptom of cadmium toxicity in plants.

Under abiotic stress, the tissues and plant cells deteriorate in response. The plant does not require a large intake of nutrients; the absence of nutrients (e.g., potassium, nitrogen, iron, and nickel) will lead to necrosis. It might happen due to soil depletion, unsuitable fertilizer application, and an imbalance of soil pH. Cadmium competes with mineral nutrients that have the same chemical properties to secure a spot in the absorption of plants. The competition between cations causes nutrient depletion in the plant. This symptom can be identified with dry papery and watery spots on plant parts. Some spots are yellow or wilted which is a sign of plant cell death activation. Necrosis might be caused due to water conditions and water source quality [35].

Stunted Growth in Plants: Plant stunting is a disease of plants because of dwarfing and loss of vigour. This symptom is caused by infectious or non-infectious bacteria, viruses, fungi, and nematodes. The non-infectious diseases are caused by the physical environment, physical or chemical injuries, and nutrient balance. In this process, cadmium absorbs and transports the macro elements; it causes growth inhibition of the root.

The high concentration of cadmium caused stunted growth and there is no production of new plantlets. Plant growth is inhibited by storing the excess cadmium ion in place of other essential micronutrients and macronutrients. The cadmium stress harms plant growth because it decreases chlorophyll concentration, which leads to a barrier to photosynthesis. This inhibition refers to the photosystem II damage that is one of the photosynthetic components [34, 36]. Another plant response system is lipid peroxidation which causes plant growth inhibition. It causes cell damage that blocks natural antioxidants in cells and water imbalance.

Photosynthesis Inhibition in Plants: Photosynthesis is one of the activities carried out by plants to maintain the existence of animals, plants, and humans. The release of cadmium into the environment has stressed the plant's photosynthetic system by destroying the chloroplast structure [37]. Cadmium reduced the chlorophyll and carotenoid content of *Brassica napus* [29]. The low amount of chlorophyll causes discoloration in leaves. Cadmium caused a substantial reduction in fluorescence efficiency, photosynthetic rate, and stomatal conductance. Plant photosynthesis activities inhibit plant growth. The photosynthesis process has been impeded by cadmium which transports electron between PSI and PSII [36].

Biomass Reduction: The absorption of cadmium by the plant impact plant health, biomass reduction, and photosynthetic efficiency. Biomass reduction because of the cadmium toxicity effect can be regarded as phytotoxicity symptoms. The rice root biomass was reduced when rice root grew in cadmium-contaminated soil [38]. The plant has tolerated up to 20mg/L of cadmium, but it resulted in plant biomass reduction with high cadmium treatment. For plant biomass reduction, cadmium inhibited plant growth [35].

Cadmium Uptake with Genes Associated: Cadmium was taken up by roots *via* a cation transport system that is involved in the uptake of plant nutrients. Zinc-regulated transport protein (ZIP), heavy metal transporting ATPase (HMA), and natural resistance-associated macrophage protein (NRAMP) families. Transporter members ZIP8 and AtIRT1 are responsible for Cd uptake by roots. In rice, Fe transporters OsZIP1, ZNT5, ZNT1, and MTP1 could transport Cadmium and they are part of Cadmium toxicity.

The P1B ATPases play an important role in transporting cadmium using the energy provided by ATP hydrolysis. The transporting members are monovalent and divalent cation groups. Three transporters are AtHMA2, AtHMA3, and AtHMA4 they are related each to other and their sequence are like the divalent cation transporters of prokaryotes. Cadmium also enters root cells as Cd-chelates through yellow stripe I-like proteins that belong to the oligopeptide transporters.

Cadmium can be translocated across the tonoplast by AtCAX4 and AtCAX2. OsLCD may be involved in cadmium transport within the rice. Cadmium might be transported into grains via low-affinity cation channels that are TaLCT1 and OsLCT1 are fixed in the plasma membrane in rice [20].

Growth Regulators of Plants: Plant stress can be caused by different techniques. Plant growth regulators have created resistance against plant stress [18, 39]. Plant growth regulators play a role in stomatal closure, plant morphology, and growth regarding the physiological role of plants. In cereals, plant growth regulators improved the leaf area, stem diameter, dry biomass, and plant growth [39]. Plant growth regulators suppressed the generation of H_2O_2, ROS, and MDA contents.

It improved the activities of antioxidant enzymes, heat shock protein, and proline content in plants [8]. Phyto stabilization is effective for the soil because it has high organic content and Phyto volatilization is a pollutant by using plants that transform a toxic pollutant that less harmful volatile material along with the plant-based transpiration cycle [1].

It has phytochromes they are Auxin, Cytokinin, Gibberellin, Abscisic acid, jasmonic acid, and Brassinosteroids. Nitric oxide and Polyamines play a role development process of plants **Table 2**. Plant growth regulators survive in Cd pollutant growing medium. Auxin, Gibberellin, and cytokinin are also involved in phytoextraction. The exogenous application of phytochromes improves plant tolerance under cadmium stress. Ascorbic acid treatment has been effective in mitigating the Cadmium that impacts rice regarding oxidative damages.

DA-6 (diethyl aminoethyl hexanoate) augmented the extraction of cadmium efficiency and enhanced the biomass accumulation [5]. Aminolaevulinic acids improved plant resistance to cadmium tolerance improving by oxidant enzymeunder cadmium-stressed soil.

Cadmium-stressed plants treated with proline increase antioxidant enzyme activities, and photosynthetic activity. PGRs can be effective to boost the growth and development of growing plants in a cadmium-stress environment [7].

TABLE 2: REMEDIATION ON PLANT GROWTH REGULATORS (PGRS) OF CADMIUM (CD) STRESS IN DIFFERENT PLANT SPECIES [44]

Plant species	Plant growth regulators	Effects on plants
Aradopsis thaliana	Auxin	Improved root growth under cadmium stress and stimulated the synthesis of polysaccharide, plant biomass and uronic acid
Parthenium hysterophorus	Gibberellin	Gibberellin accumulated 50% cadmium in the roots and reduce accumulation of nitric oxide and lipid peroxidation.
Tissues of green algae	Cytokinin	Stimulated growth of algae and activities of metabolism in cells
Brassica nigra (Mustard) *Cajanus cajan* (Pegion Pea)	Ethylene	Induced the cadmium tolerance and improved the plant biomass, photosynthetic activity, leaf area and seed germination. Cadmium induced oxidative stress
Gracilaria dura	Polyamines	It regulates the stabilization of DNA methylation by decreasing the cytosine demethylation in a mechanism to reduce the cadmium stress
Vigna radiata (Mungbean)	Abscisic Acid	Roots are improved with ABA treatments and it reduced the CAT, APX,SOD and GSH in roots under cadmium stress
Pisum sativum (Pea) *Lactuca sativa* (Lettuce)	Nitric Oxide	Improved thickness of lamina and leaf size, plant growth, biomass. Decrease cadmium uptake under cadmium stress and increase antioxidant enzyme activities, chlorophyll content.it reduced cytoplasm's in mesophyll under cadmium stress
Solanum lycopersicum (Tomato)	Brassinosteroids	It reduces the negative impacts of cadmium on growth and photosynthesis by improving antioxidant enzymes and secondary metabolism
Glycine max (Soybean) *Vicia faba* (Faba bean)	Jasmonic Acid	It may be involved in inhibition of lipid peroxide formation and stimulate non enzymatic antioxidant and increase an antioxidant enzyme. Jasmonic Acid effects on cadmium stress in faba bean plants by inhibit the accumulation of Cadmium, H_2O_2, and MDA. Its antioxidant and osmolyte activities decrease oxidative stress
Oryza sativa (Rice) *Phaseolus aureus* (Mung bean) *Vicia sativa* (common vetch) *Lemma minor* (Duckweed) *Triticum aestivum* (Wheat)	Salicylic Acid	Salicylic acid reduce cadmium induced inhibition of the photosynthetic apparatus in rice seedlings. It reduce the effects of cadmium on the SOD, POD, CAT, GR and APX. It induced cadmium tolerance associated with increases in symplastic and apoplastic antioxidant enzyme activities. It improved the synthesis of cadmium stress shock proteins in plants

Phytoremediation Technique in Plants: Remediation is eco-friendly, acceptable, and cost-effective. In this process, heavy metals can be degraded, immobilized, and removed to mitigate their impacts. Hyperaccumulator plants are used for the elimination of HMs from contaminated soils and water. Hyperaccumulators can grow on metalliferous soils and accumulate high amounts of heavy metals without phytotoxic effects. The plants are growing to absorb large amounts of HMs and accumulate shoots and leaves [30]. Plant roots secrete various compounds that help in the breakdown of contaminants. In rhizofiltration, plants absorb the HMs from the soil into their roots. Phytostabilization is the other process in phytoremediation that deals with the cultivation of plants to diminish HM by sorption, complexation, and reduction. There are various schemes, such as [40]. **Fig. 2.**

Phytostabilization is a technique utilized by plants to immobilize soil contamination through root absorption and rhizosphere absorption. Phytostabilization is the process of deactivating toxic metals from the soil environment. It depends on the capability of the root to limit the bioavailability of metals in the soil. The plant root creates contamination and reduction of the metal. it does not require the removal of soil and biomass that are contaminated. This technique stops the translocation process of heavy metals, but it does not uproot them from the soil.

Phytoextraction is a cost-effective and high-efficiency technique. It is also called phytoaccumulation which is stored in the shooting part after being extracted from the root of the plant by uptake activities from soil and water environment. Phytoextraction occurs when plants translocate metals from roots to other plant parts. This system minimizes contamination without soil composition and isolation process. It is used to remove it efficiently. Cadmium contaminants are absorbed and precipitate from the soils into biomass. Hyperaccumulation is the first scheme of phytoextraction. It removes impurities from the soil and water. The second scheme requires containing a chelating agent to enhance its solubility in soil. Plants easily absorb the solubilized metals. Its uptake heavy metals by root to shoot with an amount of biomass production. Phytoremediation is important for removing cadmium from agricultural soil. Phytostimulation is a microbial activity in the soil. It stimulates the root compound into the rhizosphere. Microbes receive nutrients for their growth. In the biotransformation process, the microbes decay the pollutants in the soil. This technique is used to remove organic pollutants from the soil ecosystem.

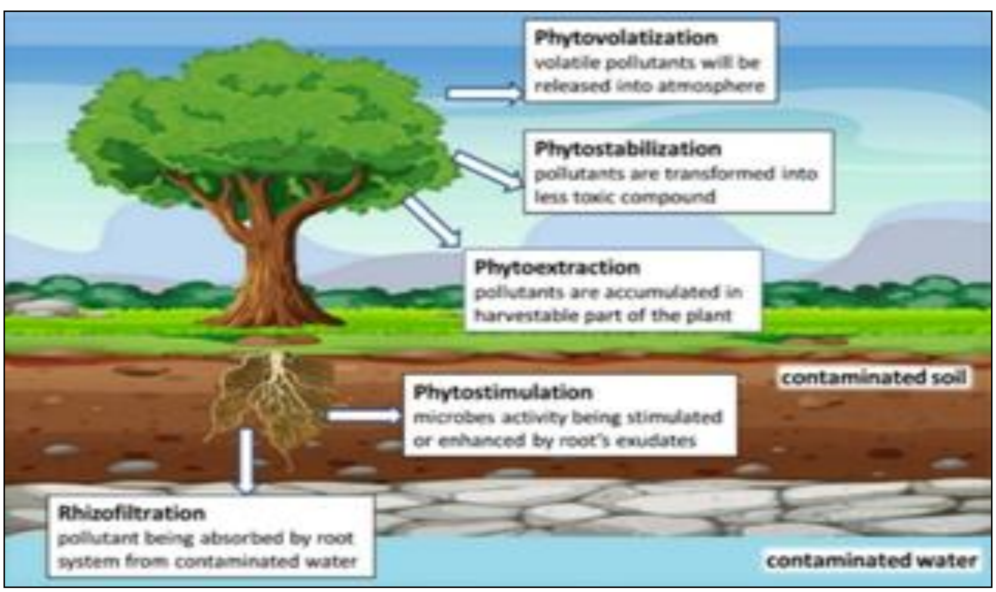

FIG. 2: PHYTOREMEDIATION OF HEAVY METALS OTHER ORGANIC POLLUTANTS IN ECOSYSTEMS [35]

Phytovolatilization is a technique to uptake contaminants by root. It conducts this process by transforming into volatile compounds. The volatile contamination will be released with the transpiration process. This technique is more successful in the remediation of organic contaminants from the soil. It does not remove toxicity permanently from the soil. Rhizofiltration is a technique that removes heavy metals from water through root biomass. The contaminants are absorbed by the root surface from the soil and environment through ion exchange, precipitation, and reverse osmosis techniques. Rhizofiltration depends on the system and structure of the root. The plants have a longer root system that provides a surface area that is most applicable for the rizofiltration technique. Rizofiltration is important for remediating most toxic heavy metals [35].

Relation between Plant and Water: Plant roots absorb inorganic nutrients and water. It protects the plant body from the ground and facilitates reproduction. The organs are recognized for toxic metals such as cadmium ions and they store high concentrations. Cadmium accumulation in tissues enhances soil water absorption. Stomata closing are caused by the interaction of cadmium ions with the guard cells. They impact the accumulation of cadmium on plant parts. The relationship between plants and water is separate from its effects on root growth, and reduced water absorption. Soil solution controls the plant water absorption levels, and it results in osmotic pressure. Cadmium stress-induced plant deceased root hair surface, secondary impaired development, that influenced plant and water relations in the soil [4, 41].

Cadmium brings a set of water-related changes in the roots of the plants. It results in a reduction in water absorption, and it inhibits the short-distance water transport in the symplast and apoplast pathways. The thick cell wall is induced by cadmium ions. That improves the apoplast. The water movement across the vascular system decreases exudation from the root sap. It decreases osmotic ability, tissue alteration of stems and leaves, and root vacuolization, which could improve the ability of water retention in plants [4]. Cadmium concentration increases the proline level in leaves and protects the plant growth and transport and uptake of plant growth. Cadmium induced stress the accumulation of osmolytes such as sucrose, glycine betaine and mannitol.

CONCLUSION: Cadmium is a pollutant in the environment. The absorption of cadmium by plants depends on the bioavailability of the element in the soil and is regulated by the soil conditions of the plantation medium. The absorption of cadmium by plant root by translocation to upper plant parts. Its results in cadmium bioaccumulation in plants. Cadmium inhibits growth and reduces photosynthesis activity. Cadmium has demonstrated the detrimental toxic symptoms of plants which are chlorosis, necrosis, and photosynthesis alteration system. Cadmium is harmful to harvesting agricultural plants and diminishes plant development, quality, and productivity.

The cadmium accumulation from root to shoot occurs when the element is taken up by roots and translocated into a shoot through xylem loading. The cadmium toxicity in plants modifies antioxidant enzymes SOD and CAT. Cadmium also produces ROS activity and lipid peroxidation. It results in dead cells and DNA modification. The consistent QTLs for cadmium tolerance were discovered in mapping populations with various genetic origins, which indicates a promise for improved breeding methods. The high concentration of cadmium in crops decelerates their photosynthetic activity. Plant nutrition is a good scheme for reducing the effects of cadmium in plants. Bioremediation technologies for decontamination of cadmium.

These different phytoremediation strategies often offer a cheaper procedure with additional windfall. The most environmentally friendly means. it's also dependable. It gives many constructive and desirable results. Positive reintegration can be achieved by extracting, transforming and stabilizing heavy metals, especially Cd, using the superior functional aspects of hyperaccumulators.

The first thing to do is evaluate them. Efficiency of phytoremediation techniques to incorporate available resources so that optimal remedial it can provide environmentally sound options for the remediation of cadmium-contaminated soils. Others, such as biochar, growth hormones, and organicmanures can use to minimize the effects of cadmium. Cd-binding gene may be used for the development of certain plants in rice. Phytoremediation in Cd-contaminated rice soil. Additionally, overexpression of some genes can occur by knocking out other genes without adverse effects.

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