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REVIEW

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Phytoremediation Potential of Aromatic and Medicinal Plants: A Way Forward for Green Economy

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Currently, interests in the cultivation of aromatic and medicinal plants gained a rapid momentum worldwide. These find great application in various industries such as; cosmetic, pharmaceutical, perfumery and other industrial sectors. Therefore, product safety issues are of paramount importance for the betterment of the consumer. Presently, heavy metal (HMs) pollution is one of the serious issues for the environment and agriculture as it has a direct impact on the production yield. This situation has worsened in the present era due to the population pressure, industrialization and various anthropogenic activities which in turn lead to oxidative stress in plants and thus disturbs the redox homeostasis and ultimate affects the quality and production yield. However, plants possess a different regulatory system that work in a synergetic manner to combat stress and thus adapts themselves in such contaminated soils. These act as sinks to neutralize the toxic effects of these heavy metals either by chelation, sequestration, intensification of enzyme system. Here we discuss the impact of heavy metals on aromatic and medicinal plants and how they play an essential role as a sustainable phytoremediation crops.

Key words: Aromatic plants, Medicinal plants, Phytoremediation, Lethal effects, Regulatory elements

The ever increasing population of the world is projected to reach 10.9 billion by 2050 and would lead to food crises in near future. Presently, agriculture sector is confronted immense challenges to provide adequate food supply, while at the same time maintain high productivity and quality standards. Current population of India is approximately 1.27 billion, thus feeding 1.27 billion mouths would indeed be a huge challenge because of degradation of soil quality due to various factors viz., mal-agricultural practices, anthropogenic activities and natural calamities that in turn affects the agro-industry. These mal-practices disturb the soil microflora by incorporating toxic heavy metals which causes shunted growth and ultimately affects the crop yield. Heavy metal toxicity is indeed a great threat to agriculture sector as it leads to oxidative stress in plants and cause deleterious effects resulting in the decline of production yield. Excessive ROS production disturbs the chemical equilibrium in plants and thus causes various oxidative damages like degradation of polyunsaturated fatty acids, leakage of ions, DNA damage and apoptosis (Rascio and Navari-Izzo, 2011; Pirzadah *et al*., 2018). Nature has engineered the plants to combat distinct biotic and abiotic stresses and thus acts as sinks for obnoxious chemicals. The plants act as green livers to neutralize the toxicity of the heavy metals either inside the plant matrix or in the rhizosphere. The detoxification of heavy metals by plants involves the co-ordinated approach at the physiological, biochemical or genomic level (Dalcorso *et al*., 2010). Generally, counteraction to heavy metal toxicity can be either accomplished by "evasion" when plants are capable to hamper metal uptake or by "tolerance" when plants sustain under huge metal concentration. The process of evasion involves the chelation or precipitation of metals in the rhizosphere and thus preventing its entry and translocation to the above ground part. In later situation, heavy metals are intra-cellularly chelated by oozing out organic acids or other metal-binding ligands (phytochelatins and metallothioneins) (Seth *et al*., 2012). The metal binding ligands such as; MTs and PCs helps the plant to absorb HM ions and sequester them inside vacuoles. The fate of the toxicity of HMs is determined by the regulation of vacuole sequestration capacity and thus it is very important to unravel its mechanism and impact on transport and sequestration. This ability of plants to extract toxic metals is nowadays been exploited to rejuvenate the soil health contaminated with various obnoxious HMs through phytoremediation process besides, the ores of economically important metals can be extracted by means of phytomining. Classical approaches to remediate heavy metal contaminated soils require a huge capital cost. Therefore, the green approach of phytotechnology for the removal of toxic metals from contaminated sites is regarded as a cost-effective, sustainable and a promising alternative to maintain the health of the soil. Many plants have the capability to grow in metalloferous soils and withstand stress and such plants can be categorized into metallophytes, pseudometallophytes or hyperaccumulators (Wenzel *et al*., 1998). However, the use of edible plants as phytoremediation crops possesses some drawbacks because the toxic metals may enter into the food chain and causes some deleterious effects. Therefore, non-edible crops such as aromatic and medicinal plants are the appropriate targets of interests to be used as potential sources of phytoremediation crops. Aromatic plants are important sources of essential oils that have potential market in perfumery, cosmetic industry and aromatherapy. Besides, the essential oils production is free from any toxic metal and thus prevents its entrance into the food chain (Khajanchi *et al*., 2013). Moreover, animals also do not damage to aromatic plants due to its fragrance and therefore it can be cultivated on large scale. Various aromatic and medicinal plants have the ability to accumulate toxic metals and are currently being exploited in phytoremediation technology. Hence, the cultivation of aromatic and medicinal plants offers a novel approach to remediate contaminated soils. Here we discuss the impact of heavy metals on aromatic and medicinal plants and how they play an essential role as a sustainable phytoremediation crops.

Heavy metals and their lethal effects in plants

Heavy metal pollution is currently a great threat to agricultural sector as it directly affects the production yield by interrupting the crop physiology. Generally, plants exhibit numerous symptoms in response to heavy metal stress which include; shunted growth and root ultrastructure (Sharma and Dubey, 2007; Pirzadah *et al*., 2018), leaf necrosis, chlorosis, turgor loss, decrease in photosynthetic activity, reduction in germination rate and percentage, apoptosis and finally death of the plant (Dalcorso *et al*., 2010; Wang *et al*., 2018). Besides, the toxicity of metal ions also disturbs the homeostasis in plants such as water uptake, transpiration, nutrient metabolism (Poschenrieder and Barcelo, 2004) and also interferes in gated ion channels (Demidchik, 2017). Lead (Pb) is not considered as an essential element besides plants does not possess lead uptake channels. However, this toxic element gets entrapped by organic acids (carboxylic group of mucilage uronic acid) on root surfaces (Sharma and Dubey, 2005), but how lead gets incorporated into the root cells is still unknown. Pb in association with other salts (sulphate and phosphate) gets precipitated thus possesses low solubility and availability to plants. As per several reports, maximum concentration of lead gets accumulated inside the root cells, thus creates a primary obstruction for the Pb translocation to the above-ground parts of the plant (Blaylock and Huang, 2000), acting like an innate barrier. Accumulation of Pb in plants has several lethal effects on their physiology and biochemical parameters (growth, morphology and photosynthesis). The enzymes get inactivated under high Pb concentration by binding with their sulfhydryl (-SH) groups. However, the tolerance of plants to Pb concentration varies depending upon the species and nature of mechanism. Some plants are prone to Pb concentration while as some are tolerant and they have the capability to accumulate high Pb concentration and are considered as hyperaccumulators. Buckwheat has tremendous potential to tolerate and accumulate high Pb concentration in their leaves without showing any significant damage (Horbowicz *et al*., 2013). On dry weight basis buckwheat accumulates approximately about 1000mg/Kg of Pb in its shoots thus is regarded as an excellent hyperaccumulator (Pirzadah *et al*., 2014). Reports also revealed that buckwheat accumulates high Pb concentration in various parts of the plant such as in leaves (8000mg/Kg), stem (2000mg/Kg) and roots (3300mg/Kg) on dry weight basis without showing any lethal damage (Tamura *et al*., 2005). In another study, Pb is involved to inhibit the elongation of stem and root and expansion of leaf as in observed in *Allium* species (Gruenhage and Jager, 1985), *Raphanus sativus* and barley (Juwarkar and Shende, 1986) but the intensity of elongation depends on various parameters such as concentration gradient, ionic composition as well as pH of the medium (Pourrut *et al*., 2011). Aluminium (Al) which constitutes about 7% of the earth's crusts ranked third most abundant element after oxygen and silicon. Major portion of the Al occurs as oxides and alumino-silicates which are harmless compounds however, when soil becomes acidic due to anthropogenic activities, Al gets solubilized into the lethal form (Al^{3+}). The toxicity of Al inhibits plant growth and thus affects the agricultural yield (Smirnov *et al*., 2014). Al not only causes shunted growth and development of plants but also inhibits root and shoot elongation thus declines the biomass production. The immediate adverse effects of Al-toxicity is root inhibition and elongation by destroying the root apex (Zheng, 2010), thus interferes in water and mineral uptake. Moreover, Al is also involved to halt the action of proton pumps on endosomes which in turn traps transferrin-bound iron inside these vesicles thus acts as a barrier in stimulation of ferritin synthesis. In addition to this Al also causes an oxidative stress though even it is not a redox metal (Liu *et al*., 2008). Besides, Al possesses the capacity to form electrostatic bonds preferably with oxygen donor ligands (viz. phosphates), cell wall pectin and outer surface of the plasma membrane (Yamamoto *et al*., 2001). Some reports also revealed that binding of Al to bio-membranes results in rigidification (Jones *et al*., 2006) which in turn facilitates the radicle chain reaction by iron ions and thus boosts the peroxidation of lipid as is reported in various species like barley (Guo *et al*., 2004), triticale (Liu *et al*., 2008), wheat (Hossain *et al*., 2005) and green gram (Panda *et al*., 2003). Higher Al concentration also leads to calcium and magnesium deficiency (Jones *et al*., 1998). The level of Al toxicity varies from species to species; some plants are very prone to Al-induced stress even at micro-molar (µM) concentration while some species exhibits high resistance. Among various plant species, buckwheat, tea, mangroves and certain other grass species have the ability to develop symplastic tolerance mechanism and thus accumulates higher Al concentration in the above-ground parts. Buckwheat has the large tendency to accumulate approximately about 1500 mg/Kg Al-concentration mainly in the form of Al-oxalates in the leaves without any lethal effect (Ma *et al*., 1997; Zhang *et al*., 1998). Mercury (Hg) another most toxic HM that has devastating effect on the agricultural production. It generally occurs in different forms such as mercury sulphide (HgS), Hg^{2+}, Hg^0 and methyl-mercury (CH_3Hg^+), but the predominant form of Hg in the agricultural land is ionic form i.e., Hg^{2+} (Pirzadah *et al*., 2018). Hg possesses the unique property to remain in solid phase by binding onto the clay particles, sulphides or other organic matter. This toxic metal has the tendency to get accumulated in various plant parts especially higher plant species (Israr *et al*., 2006), where it causes deleterious effects to the plant cells and tissues. For instance, closure of stomata and blockade of water flow in plants by gets binding with water channel proteins (Zhang and Tyerman, 1999). Besides, Hg toxicity also hamper the mitochondrial activity which is usually considered as a power house of the cell and induces the oxidative stress which in turn leads to the generation of ROS, thus enhances the lipid peroxidation and ultimately disrupts the integrity of bio-membrane (Cargnelutti *et al*., 2006; Pirzadah *et al*., 2018).

Mechanism of action of toxic metals in plant cells

Plants have developed various ways to detoxify HMs toxicity when accumulated at huge concentration levels. Usually, these heavy metals are categorized into two types which include: redox active (Co, Cr, Cu, Fe etc) and redox inactive (Mn, Pb, Cd, Hg, As, Ni etc). The redox active heavy metals play a direct role in generating ROS through various chemical reactions like Fenton and Haber-Weiss reactions (Schutzendubel and Polle, 2002; Cuypers *et al*., 2016). The second category of heavy metals plays an indirect role to induce oxidative stress like interference with enzyme defense system, disruption of the electron transport chain and lipid peroxidation initiation due to enhanced lipoxygenase activity. Moreover, heavy metals also possess the capability to bind firmly with atoms such as; nitrogen, sulphur and oxygen that is associated to free enthalpy of the formation of the product of the HM and ligand and reduce their solubility. Besides, these HMs also inactivate the enzymes by binding their thiol-group, for instance, binding of heavy metal like cadmium (Cd) to sulfhydryl group of structural enzymes and proteins either results in mis-folding and arrest of enzyme action or impede with redox enzymatic regulation (Dalcorso *et al*., 2008; Hossain *et al*., 2012; Gill, 2014). Most of the enzymes need cofactors which are regarded as helper molecules to aid in biological activity. These cofactors may be either inorganic (Mg^{2+}, Ca^{2+}, Cu^{2+}, Fe^{2+}) or organic (biotin, FAD, NAD) origin and replacement of any cofactor halts the enzyme action. For instance, displacement of magnesium (Mg^{2+}) in ribulose-1,5-bisphosphate-carboxylase/oxygenase (RuBisCO) by Co^{2+}, Zn^{2+} and Ni^{2+} thus halts the activity of enzymes (Sharma and Dubey, 2005; Gill, 2014). Moreover, these HMs are also responsible for disruption of bio-membranes by enhancing the lipid peroxidation, oxidation of thiol-group of proteins and blockage of basic membrane proteins (H^+-ATPase) (Meharg, 1993; Hossain *et al*., 2012). Furthermore, these toxic heavy metals also leads to the initiation, production and accumulation of most lethal compounds like methylglyoxal-a cytotoxic chemical due to disruption of glyoxalase system that finally elicits oxidative stress by diminishing the glutathione content (Hossain and Fujita, 2010; Hossain and Hasanuzzaman, 2011).

Role of Metallothioneins (MT)

MT's are metal binding low molecular weight cysteine rich proteins that are generally synthesized during mRNA translation (Kagi, 1991). These metalloproteins has got immense potential to sequester numerous HM like Cd/ Pb/ Hg/ Cu/ Zn etc by binding via thiol group (-SH) of cysteine residues thus is involved in the homeostasis and detoxification of heavy metal toxicity (Goldsbrough, 2000; Komal *et al*., 2014; Pirzadah *et al*., 2014; Tripathi *et al*., 2015). The structure of MT revealed that it possesses two metal binding domains which are assembled from cysteine clusters. These include α-domain (N-terminal) which bears three binding sites for divalent ion and β-domain (C-terminal) which has the capability to bind with four divalent ions of heavy metals. In plants, the genes encoded these metallo-proteins are influenced by stress conditions viz., HM, cold stress, drought stress etc. (Berta *et al*., 2009; Jia *et al*., 2012). These MT are usually regarded as major transition metal ion binding proteins in cells because they mainly form the complex compounds with Cu, Zn (essential metals) but bear less capacity to bind with Cd, Hg Pb etc. Besides, some researchers also reported that these metallo-proteins also act as a shielding agent to protect plants from oxidative stress by removing free radicles (Jia *et al*., 2012). Nowadays researchers are very interested in determining the ROS scavenging activity of these MT besides developing databases containing gene sequences of MT that acts as a repository to generate HM resistant plants (Leszczyszyn *et al*., 2013). However, the transaction between metal binding and ROS scavenging is still unknown yet. It has been reported that during scavenging of ROS, metal ions would be released when free radicles gets bound to cysteine residues of these metallo-proteins. Few authors suggested that the released metals might be involved in signaling cascade. Various MT-types have been reported from plants like rice, oil palm, hybrid poplar, buckwheat and lichens besides many cDNA encoding MT-genes have been isolated (Backor and Loppi, 2009). It has been reported that buckwheat cDNA clone (PBM290) which encode MT-like proteins was isolated from cDNA library and the reduced amino acid sequence reveals its maximal homology with MT3-like protein isolated from *Arabidopsis thaliana*. Upon expression analysis it is found that buckwheat MT3 mRNAs seem to be present in tissues of root and leaf during development of seed under normal circumstances and its expression is greatly altered by HM stress (Pirzadah *et al*., 2014).

Role of transcription factors (TFs)

Hyperaccumulating plant species contain several metal TFs that are involved in various regulatory pathways to detoxify HMs and some have been already identified in various plant species that imparts HM tolerance and these TFs belong to different families viz., WRKY, basic leucine zipper (bzip), ethylene-responsive factor (ERF) and Myeloblastosis protein (Myb) (Fusco *et al*., 2005; Van De Mortel *et al*., 2008). Van De Mortel *et al*., (2006) reported that under Zn-sufficient conditions, 131 TFs showed 5-times more expression in *T. caerulescens* compared to *A. thaliana*. Similarly, Ban *et al*., (2011) reported that Cd and Cu cause either up-regulation or down-regulation of dehydration responsive element-binding protein (DREB). Another important metal transporter known as (natural resistance associated macrophage protein) NRAMP found in fungi, bacteria, animals and plants and is responsible to transport a wide variety of metal ions viz.,Cd^{2+}, Zn^{2+}, Cu^{2+}. Ni^{2+}, Co^{2+}, Fe^{2+} and Mn^{2+} across membranes (Nevo and Nelson, 2006). In case of plants there type of transporters are usually expressed in roots and shoots and are engaged to transport metal ions through plasma membrane and tonoplast (Schmidt *et al*., 2007). It has been reported that NRAMPs in *Arabidopsis thaliana* play a significant role to transport iron (Fe) and Cadmium (Cd), however NRAMP1 exhibits Fe transport specificity and homeostasis (Thomine *et al*., 2000). Other transporters involved in sequestration of HMs include ATP-binding cassette (ABC) transporters, cation diffusion facilitator (CDF) transporters, heavy metal ATPases (HMA) transporters etc. These are actually intracellular transporters that are involved to carry out the transport of xenobiotics and toxic heavy metals into the vacuole. Multidrug resistance-associated proteins (MRP) and pleiotropic drug resistance (PDR) transporters are two sub-families involved in sequestration of chelated heavy metals (Lee *et al*., 2005). In case of plants, vacuoles are considered as dominant sites for accumulation and storage of phytochelatins-Cadmium (PC-Cd) complexes. Usually cytosol is the major site where these complexes are generated and are then translocated by means of ABC-transporters (Yazaki, 2006). HMT1 is the first vacuolar transporter present in the tonoplast and is responsible to transport PC-Cd complexes inside the vacuole in a magnesium-adenosine triphosphate-dependent (Mg-ATP) manner (Yazaki, 2006). Salt and Rauser (1995) reported similar homolog protein (HMT1) in oat roots. Magnesium proton exchanger (MHX) and (Cation eXchangers) CAX-transporters are the members of calcium-calmodulin (CaCA) families and are responsible for metal homeostasis. (MHX) first identified in vacuolar vesicles of rubber tree (*Hevea brasiliensis*) and is magnesium (Mg^{2+}) and zinc (Zn^{2+})/H^{+} antiport dominantly expressed in xylem-associated cells. However, overexpression of these transporters enhances sensitivity to Mg and Zn, in spite the titre of the metals in shoots is unchanged (Shaul *et al*., 1999). Besides, CAX family are considered as Ca^{2+}/H^{+} antiports helps to recognize Cd^{2+}-ions, thus is involved in Cd-sequestration inside the vacuoles (Salt and Wagner, 1993). AtCAX2 and AtCAX4 are two CAX proteins reported in *A. thaliana* and possess an essential role in accumulation of Cd inside the vacuoles. Korenkov *et al*., (2007) reported that overexpression of AtCAX2 and AtCAX4 leads the accumulation of large concentration of Cd inside the vacuoles. Moreover, AtCAX4 is usually expressed in primordia and a root tip, besides it is induced by nickel (Ni) and manganese (Mn).

Current update on the use of aromatic and medicinal plants in phytoremediation technology

The current update on the use of aromatic and medicinal plants as sustainable phytoremediation crops is illustrated in Table 1.

Table 1. An update on the use of aromatic and medicinal plants as phytoremediation crops

Plant	Metal	Reference
Cymbopogon citratus	Cd, As, Ni, Cu, Fe	Jisha *et al*. (2017)
Vetiveria zizanioides	Cd and Pb	Ng *et al*. (2017)
Ocimum basilicum	Cd	Alamo-Nole *et al*. (2017)
Mentha arvensis	Cu, Zn	Malinowska and Jankowski (2017)
Vetiveria zizanioides	Cu, Pb, Sn, Zn	Vo *et al*. (2011)
lemongrass	Pb, Cd, Zn	Hassan *et al*. (2016)
Euphorbia hirta	Cd	Hamzah *et al*. (2016)
Cymbopogon citratus	Pb(II), Cd(II), Zn(II)	Hassan (2016)
Ocimum basilicum	Cr, Cd	Zahedifara *et al*. (2016)
Mentha crispa	Pb	Sa *et al*. (2015)
Mentha species	Ni, Cr, Cd, Al	Manikandan *et al*. (2015)
Ocimum basilicum	Cd and Zn	Akoumianaki-Ioannidou *et al*. (2015)
Lavandula vera	Pb, Zn, Cd	Angelova *et al*. (2015)
Rosmarinus officinalis	Cd and Pb	Ramazanpour (2015)
Cymbopogon flexuosus	Cr	Patra *et al*. (2015)
Euphorbia hirta	Radioactive waste	Hu *et al*. (2014)
Cymbopogon citratus	Pb	Sobh *et al*. (2014)
Ocimum basilicum	Cd, Pb, Zn	Stancheva *et al*. (2014)
Vetiveria zizanioides	Cd , Ni	Gunwal *et al*. (2014)
Cymbopogon citratus	Ni	Lee *et al*. (2014)
Matricaria chamomilla	Cd , Pb, Zn	Stancheva *et al*. (2014)
Catharanthus roseus	Cd, Pb, Ni, Cr	Ahmad and Misra (2014)
Ocimum tenuiflorum	As	Siddiqui *et al*. (2013)
M. chamomilla	Cd, Pb	Voyslavov *et al*. (2013)
Cymbopogon winterianus	Cr	Sinha *et al*. (2013)
Vetiveria zizanioides	Cu, Zn, Pb	Chen *et al*. (2012)
Chrysopogon zizanioides	Hg	Mangkoedihardjo and Triastuti (2011)
Aloe vera	Cr	Sharma and Adholeya (2011)
Ocimum basilicum	Cr, Cd, Pb, Ni	Prasad *et al*. (2010)
Pelargonium sps.	Pb	Abdullah and Sarem (2010)
Hypericum sp.	Cd	Tirillini *et al*. (2006)
Ocimum tenuiflorum	Cr	Rai *et al*. (2004)
Hypericum perforatum	Cd	Schneider and Marquard (1996)
Senecio coronatus	Ni	Przybylowics *et al*. (1995)

Table 2. Observed phyto-technologies in some aromatic plants.

Name of plant	Observed Phyto-technologies	Possible heavy metals to be remediated
Vetiver	Phytostabilizer	Cd, Pb, Cu, As, Hg, Cr, Ni, Sn, Zn
Lemongrass	Phytostabilizer	Cd, Hg, Pb, Cu, Ni, Cr
Palmarosa	Phytostabilizer	Cr, Cd, Pb, Ni, Fe, Zn, Cu
Citronella	Phytostabilizer	Cd, Cr
Ocimum	Phytostabilizer	Cr, Cd, Ni, Pb, As, Zn
Salvia	Hyper accumulator for certain heavy metals	Cd, Pb, Cr
Mint	Phytostabilizer	Cr, Pb, Ni, Cd, Cu, Zn,
Rosemary	Potential bio-monitor, Phytostabilizer as well as hyper accumulator of Ni.	Hg, Pb, Cu, Zn, Cd, Ni, Fe, As, Sb
Chamomile	Facultative metallophytes or metal excluders, Cd accumulating species.	Cd, Zn, Cu, Pb, Ni
Geranium	Hyper accumulator for certain heavy metals.	Cd, Ni, Pb, Zn
Lavender	Hyper accumulator for certain heavy metals	Cd, Pb, Cu, Zn, Fe

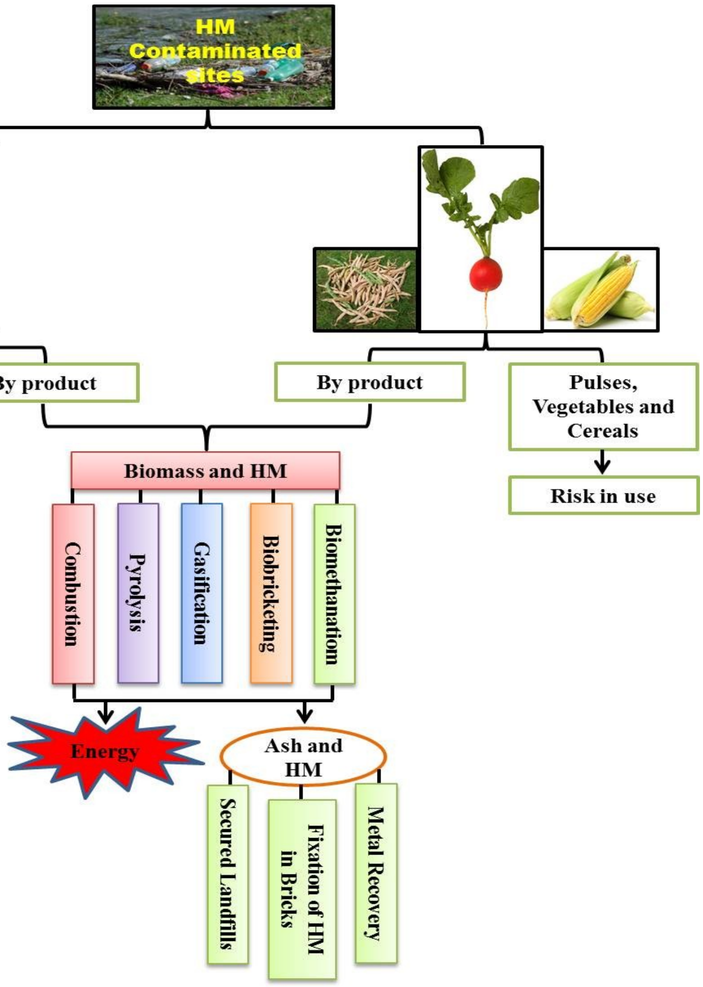

Figure 1 Graphical representation showing benefits of aromatic plants for phytoremediation

Aromatic and medicinal plants as sustainable phytoremediation crops

Remediation of soil health contaminated with toxic metals by utilizing aromatic plants than non-aromatic edible crops is a promising and sustainable approach. Till date, few data is available where aromatic and medicinal plants were utilizing as prominent phytoremediation crops (Gupta *et al*., 2013). Vamerali *et al*., (2010) carried out a metadata analysis and reported that few data is available regarding the utilization of aromatic plants as phytoremediation crops. Metadata analysis revealed that an edible oil crop *Brassica juncea* was mostly cited (148 citations) followed by *Helianthus annuus* (57 citations), *B. napus*, and *Zea mays* (both 39 citations). This indicates that aromatic and medicinal plants were given a least significance as phytoremediation crops. However the use of non-aromatic crops for phytoremediation is not viable because the toxic heavy metals may accumulate into their edible parts and thus enter the food chain either consumed by animals or humans. Therefore, the main thrust was currently focused on aromatic plants which are used for the production of essential oils. These are non-edible and are not being consumed directly like vegetables and staple foods besides they possess efficient check points to reduce toxic metal translocation from soil to essential oils or carried out any alteration in its chemical composition (Zheljazkov *et al*., 2006) which is due to the process used for oil extraction (Scora and Chang, 1997; Bernstein *et al*., 2009; Pandey and Singh, 2015). It has been proved that there is least risk of heavy metal contamination in essential oil obtained through steam distillation process as heavy metals remain in the extracted plant. Hence, it can be acceptable in the market (Scora and Chang, 1997; Zheljazkov and Nielsen, 1996). Majority of the promising aromatic plants for phytoremediation of toxic metal contaminated sites have been identified from families – *Poaceae*, *Lamiaceae*, *Asteraceae* and *Geraniaceae*. Utilizing aromatic and medicinal plants is a novel approach to rejuvenate contaminated soils and currently number of plants viz., vetiver (*Vetiveria zizanioides*), palmarosa (*Cymbopogon martinii*), lemon grass (*Cymbopogon flexuosus*), citronella (*Cymbopogon winterianus*), geranium mint (*Mentha sp.*), tulsi (*Ocimum basilicum*) are ecologically feasible and viable. Some aromatic grasses like, lemon grass, palmarosa, citronella, vetiver, etc. are stress tolerant and perennial in nature. Table 2 represents the observed phyto-technologies of various aromatic and medicinal plants. Besides, there is high demand for the essential oils at the international market because of their significant role in different industrial sectors viz., perfumery, aromatherapy and cosmetic industry and it is predicted that the potential market for essential oils would reach to US$5 trillion by 2050 (Verma *et al*., 2014). In order to cater the ever increasing demand of essential oil, aromatic grasses possess the huge potential as these can be grown on contaminated sites to restore the soil health besides oil production and eco-tourism (Fig. 1).

Conclusion and further perspective

HM contamination is increasing at an alarming rate due to numerous anthropogenic activities which in turn affects plant health thus declines the production yield. Even though several species possess the capacity to hyper-accumulate these HMs thus resists the oxidative stress while some are prone to HM stress. Generally, plants have the innate ability to detoxify HMs by means of several ways like exclusion, chelation and sequestration. Nowadays research must be focused on non-edible crops such as; aromatic plants as they have great potential in remediating soils contaminated with toxic metals, besides reports revealed that the essential oil production gets enhanced under heavy metal stress as these acts as an elucidating agents. Phytoremediation is a sustainable approach in the phyto-management programme to rejuvenate soil health; therefore a comprehensive research is needed for utilizing aromatic and medicinal plants as phytoremediation crops that may lead to green scented technology. This approach of using green scented technology is cost-effective and reduces the risks of food chain contamination. In future, multiple stress factors will be investigated as it happens in real environmental conditions. An interdisciplinary approach is necessary to unravel the molecular mechanisms involved in HM-stress. In addition to above, plant-metal interaction is also indispensible for numerous purposes such as;

(1) Prognosis health hazards caused by metal bioaccumulation in crops failing visible manifestations of phytotoxicity.

(2) Bio-fortification i.e. design plants in such a way that they can accumulate metals indispensable for human health.

(3) Rejuvenate soil health (phytoremediation) and excavation of rare metals through green route (phytomining).

CONCLUSION AND FURTHER PERSPECTIVE

By dint to their antioxidant property, exogenous spermine exert a stimulating effect on several Physiological processes in the tomato plant. As shown in this study, the combination of this polyamine with cadmium makes it possible to reduce the disturbances caused by this metal stress, such as the recovery of weight, and the content of photosynthetic pigments as well as the stimulation of antioxidant enzymes. Nevertheless, because of the expensive price of polyamine, this has further research needed on the treatment time of exogenous spermine application to take advantage of their large-scale.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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