International Journal of Research Publication and Reviews, Vol (5), Issue (6), June (2024), Page – 5047-5051

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Heavy Metal Acquisition and Retention :A Study

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ABSTRACT:

Heavy metal (HM) poisoning of agricultural soils poses a serious risk to plant life, human health, and global food supply. When HM levels in agricultural soils get to dangerous levels, it harms crop health and yield. Chromium (Cr), arsenic (As), nickel (Ni), cadmium (Cd), lead (Pb), mercury (Hg), zinc (Zn), and copper (Cu) are the main heavy metals. The environment contains these metals in varying degrees, such as in soil, food, water, and even the air.

Keywords:-Phylum,soil binding,Cycling,Trunks,Nature

INTRODUCTION :

Bryophytes, the 'amphibians of the plant kingdom', occupy almost all kind of habitats in almost all parts of the globe. They are a group of plants that ventured first on the barren land during the origin and evolution of land plants. They consist of diverse and distinct group of primitive plants with about 23,000 species (grouped under nearly 960 genera) (Shaw and Goffinet, 2008) making it the second largest phylum of land plants after angiosperms. Their individuals grow closely packed together in the form of mats or cushions on rocks, soils, or as epiphytes on the trunks and leaves of trees. Even though neglected for the lack of direct economic importance or an unassuming nature; they play important role in ecosystem dynamics, nutrient cycling, soil binding, providing microhabitats for other plants and animals, fill gaps in the habitats and promote plant succession, etc. They constitute a distinctive component of the forest ecosystem, particularly in cooler northern and southern latitudes and extremely humid climates of both temperate and tropical regions. They serve as ideal study material giving insight into the plant evolution, adaptation, monitoring the ecosystem health and pollution levels.
Bryophytes appear to be an "Ecological Keystone" group in the temperate rain forests, where the forest-patches and corridors are almost conferred by variety of bryophytes. In bryophytes the average height of the plant is 6-7cm. However, Dawsonia superba may reach a height of about 70 cm (Sainsbury, 1955), and Polytrichum commune can be nearly as tall as 50 cm. The length of hanging axis of Meteorium can reach up to 80 cm and reclining axis of aquatic moss Fontinalis may be up to 1m. On the other hand some of the taxa are quite small, ranging down to such tiny plants as species of Cephaloziella, Ephemerum and Micromitrium barely visible to the naked eyes. The life cycle of bryophytes remain unique as it displays two alternating generations with short lived, dependent sporophytic phase and the dominant gametophytic phase; their growth and sexual reproduction depends on external water and is therefore favoured by a humid microclimate. They show a wide range of physiological and dispersal adaptations (Smith 1984; Proctor 1981; Bates and Farmer 1992; Longton 1997). Various modes of reproduction play an important role in the life cycle of bryophytes especially in stands within high disturbance
(Bisang 1996).

SPECIES RICHNESS AND DISTRIBUTION

Bryophytes are a heterogeneous division of the plants kingdom which includes the three classes: the liverworts (Hepaticopsida), hornworts (Anthocerotopsida) and the mosses (Bryopsida) (Schuster, 1984). Hepaticopsida (Liverworts) are a group of thalloid and distichous leafy forms of about 14 orders, 74 families, 330 genera and 8,000 species (Stotler, 2000). Anthocerotopsida (Hornworts) are a small group of fragile thalloid forms, having a single order Anthocerotales, 2 families, and 11 genera with nearly 1,000 species (Renzaglia and Vaughn, 2000). Bryopsida (Mosses) are the largest group of leafy forms, with over 21 orders (with Hypnales being the largest order with 44 families), 117 families, 650 genera and 14,000 species
(Buck and Goffinet, 2000). Mosses has achieved remarkable success in colonizing diverse habitats i.e. soil (terrestrial), rocks (lithophytes), trunks and twigs (epiphytic), leaves (epiphylls), bushes, stream banks, muddy edges of rivers and lakes, under water falls (aquatic) and dark caves (e.g. Schistostega pennata). The efficient dispersal methods, variable life strategy and short life cycle of ephemeral species (e.g. Physcomitrella, Phascum) enable them to colonise even the habitats available for short durations. Pande (1958) described 7 bryogeographical regions in India namely –1. The Himalayan Region including (i) The West Himalayan Territory, (ii) The East Himalayan Territory, 2. The Punjab and the West Rajasthan Plains, 3. Central India and the Gangetic Plains, 4. Southern zone including (i) the West Coast Region, (ii) the East Coast Region. Majority of moss flora lies in four major zones viz. Western Himalaya harbour nearly 722 species, Eastern Himalaya encompasses 788 species, South India comprises 592 reported species, while central India has 59 species. Of these 194 species of mosses are reported to be endemic.

HABITAT

Bryophytes are popularly known as “pioneers” of succession on substrate that occupy barren land and make it habitable by attracting a variety of organisms. Bryophytes are abundantly found in cool and humid areas but in drought or unfavorable climatic conditions they prefer niches such as crevices of rocks, grooves of tree bark and sometimes near the shady streams. The distribution of bryophytes are effected first by microclimatic factors i.e. Rain fall and temperature, latitude and altitude (Pitkin 1975; Sveinbjörnsson and Oechel 1992) and then by micro environmental conditions like shade, humidity, humus and temperature (Yarranton and Beasleigh 1969). The occurrence of bryophytes may be effected by side factors e.g. age of the soil, rocks, composition of forest soil, moisture content (McCune 1994; Sillett and Neitlich 1996) and by substratum like its pH and its humus status (Wolsely and Aguirre-Hudson 1997; Batty et. al. 2003). Bryophytes are able to absorb water over their entire surface (ectohydric) and easily lose it to the atmosphere in dry weather. Some forms such as Tortula ruralis may survive long periods of desiccation without being damaged while others are ephemerals and remain as spores during severe water deficit. The dried plants can resume photosynthesis and respiration within a short period of time after rehydration. Poikilohydric mosses are able to survive complete desiccation for months and even for years without irreversible damage and recover their full activity as soon the water supply is sufficient. Epiphytic bryophytes play an important role in the ecology of forest communities and they are more abundant in tropical angiosperm forest. Epiphytes need irregular surface of bark and twigs and depression on branches as well as they require fissures for their establishment, which provide a place for them as well as humus and moisture. A specific seed plant community provides a favorable micro-environment to specific bryophytic vegetation. Thus, it can be useful in characterizing a site in some areas as the particular bryophyte vegetation can inform about the past vegetation and can be used to improvise plantation programme of a particular vascular plants in that area. Many mosses grow on particular mineral rich substrata. e.g. Mielichhoferia, Merceya, Barbula and Scopelophila represent to be related with Copper rich substrata. The patches of Hyophila, Oxystegus and Zygodon indicate iron hematite bearing substrates at the particular site. Some bryophytes have capability to absorb the minerals in large quantity than absorbed by other higher plants of the same site. Lack of cuticle, presence of single cell thick lamina, large surface area by volume ratio and high cation exchange capacity make the bryophytes a suitable accumulator. Bryophytes make characteristic communities on some habitats. Epiliths grow only on rocks and have some special adaptation, perhaps need a permanent habitat, require less water and their competitive capability to grow on such substrata such as Tortella, Gymnostomum, Grimmia, Porella etc. Some communities are able to grow on mobile sand; they can disappear over night and may reappear shortly after a shower of rain or humidity. Funaria, Bryum, Barbula and Tortula grow on freshly disturbed soil and on road cutting. Some bryophytes are found on rocks which are rich in calcium carbonate and where water flows over or percolates through these rocks such as Philonotis, Fissidens. They have 3- 4 times greater calcium exchange capacity (Bates, 1978). On the other hand some grow on potassium containing substrata with an acid reaction or in soft waters such as Andreaea rothii, Scapania undulata etc. Funaria hygrometrica, Ceratodon purpureus, Bryum argenteum grow on the high pH (8-10) substrata where high percentage of potassium, phosphates and magnesium along with nitrogen and other organic matter are accumulated after fire. Members of family Splachnaceae are adapted to live on nitrogenous substrata such as animal excreta.

GROWTH FORMS

Bryophytes have evolved various adaptive strategies for balancing the benefits and costs of having a high affinity for resources, plasticity of growth allocation and mycorrhizal symbiosis. The growth in particular is a relatively constant characteristic of some plant species. The general appearance of colonies of mosses is largely governed by the growth forms of their shoots and somespecies always present a characteristic appearance (Du Rietz 1940). Gimingham and Robertson (1950) described the classification of growth forms based on morphology only. Growth forms enhance the water and nutrient trapping ability. Different types of growth forms are as follows: Cushions: The shoot radiate from a central point of origin and branches adopt same direction of growth as main shoots. Branching appears from near apex of shoot and adding to the size of the cushion. Leucobryum glaucum, Schistochila, Orthotrichum, Grimmia, Ulota, Plagiopus, Calymperes and Syrrhopodon etc. Turfs: The main shoot and its branches are erect and the direction of growth is vertical. Bryum argenteum, Ceratodon purpureus form turfs. Canopy: The erect portion of the shoot is unbranched below with scale leaves and normal leaves usually abundant on branch at the tip forming canopy. e.g. Pogonatum, Climacium and Rhodobryum. Mats: The shoot system forms a dense and interwoven mat, extending horizontally over the substratum. The main shoots are creeping over substratum often with rhizoids. There is abundance of lateral branches with limited growth. The mat forms exist in Brachythecium, Plagiothecium, Homalothecium,

Taxithelium.

Thread: The delicate, creeping shoots are irregularly and sparingly branched sometimes forms open mats. This form is adopted by many species such as Eurhynchium praelongum when occurs sparingly among other vegetation. Thalloid Mats: The thalloid taxa form the overlapping dorsiventral thalli as found in Pellia, Symphogynae, Dumortiera, Marchantiaceae and Metzgeriaceae. Wefts: Systems developed as a result of the loose inter-twining of straggling shoots and branches often ascending and luxuriant. The branches are often arching or ascending. A new layer is formed growing every year over previous year shoots. Weft forming taxa are members of Hylocomiaceae, Thuidium and Rhacopilum. Pendants: The main shoots hang down from the branches and twigs of trees and laterals shoots remain short and stand out horizontally. Pendant forming taxa are Meteorium, Meteoriopsis and Cryptoleptodon Fan: Some creeping mosses growing on a vertical base (tree trunks, rocks) throw branches towards one side in the same plane, project horizontally to obliquely downwards and usually have flattened leaves. Fan forms are displayed by Thamnobryum, Echinodontium, Bryopteris and Neckeraceae. Feather: The secondary stems are more or less pinnately branched and are placed dorsiventrally. They are epiphytic or saxicolous e.g. Hypopterygium, Neckeropsis, Callicosta bipinnata.

BRYOPHYTES AS MONITORS AND ACCUMULATORS OF ENVIRONMENTAL CONTAMINANTS

The idea of deducing the effects of pollution on human health through the use of biomonitors is fascinating. Cislaghi and Nimis (1997) supported the hypothesis that lung cancer is correlated with the diversity of epiphytic lichens as a result of air pollution. Wappelhorst et al. (2000) found correlations between the content of some element in mosses and occurrence and incidence of cardiovascular and respiratory diseases. Similarly, Sarmento et al. (2008) reported some association between the concentration of chemical elements obtained through atmospheric biomonitoring with lichens and cancer mortality. Bryophytes are popular organisms for biomonitoring to determine levels and identify sources of elements. They may be used to integrate the deposition over considerable time, usually 2–5 years, depending on species and sampling metals because of longevity abundance and wide distribution of most bryophytes. Surveys of metal accumulators in mosses have been attempted in number of countries (Markert et al. 1996). In areas where natural bryophytes vegetation is poor owing to atmospheric pollution or other stresses, metal deposition can be surveyed by transplanting bryophytes or employing moss-bags (Taoda, 1973a,b). Impoverishment of bryophytic communities has been observed in and around cities and industrial areas (Barkman, 1958; Le Blanc & Rao, 1966; Gilbert 1968, Daly 1970). Transplantation experiments have shown that bryophytes die within a short period of time, depending on the level of pollution, when transferred along with their substrates from unpolluted to polluted areas in a city or around an industrial site (Le Blanc & Rao, 1966; Daly 1970; Le Blanc et al. 1971, 1974). Metal accumulation depends mainly on particulate trapping and cation-exchange capacity (Brown 1984). Tuba and Csintalan et al. (1999) described the exposure of living cushions of Tortula ruralis within wooden boxes for three months to determine metal deposition in and around an industrial town. For better understanding of environmental changes in past 40 years in Shanghai, the spatial and temporal changes of five heavy metal depositions in two species of moss genus Haplocladium were observed. The concentration of Cd, Cr, Cu, Pb, Zn in the samples of moss Haplocladium collected from 16 sites in Shinghai in 1965, 1974-76, 1978-1982, and 2005 were determined. The result showed that the concentrations of five heavy metals at all sample site increased distinctly from 1965-2005, especially after the 1980's. The increasing rate was Cr>Cu>Cd>P>Zn The heavy metal concentration was distinctly associated with local emission point source and changes in emission levels and the major emission were industry and traffic. (Cao et al., 2008).

HEAVY METALS

Heavy metals are natural components of the Earth's crust that are persistent and cannot be degraded or destroyed from the environment. Heavy metals have relatively high density and are toxic or poisonous at low concentrations. They have atomic weights between 63.546 and 200.590, and a specific gravity greater than 4.0. Heavy metals are enriched in the environment by human activities which end up in outlets and wastes where heavy metals are transported to the environment by air, water or deposits, thereby increasing the metal concentrations in the environment. Heavy metals are released in the environment through:

- Mining activities (smelting, river dredging, mine spoils and tailings, metal industries etc.).
- Industries (plastic, textiles, microelectronics, wood preservatives, refineries etc.).
- Atmospheric deposition (urban refuse disposal, pyrometallurgical industries, automobile exhausts, fossil fuel combustion etc.).
- Excessive use of agrochemicals (fertilizers and pesticides) and waste disposal (sewage sludge, leachate when the former is used as landfill). Metals reach terrestrial bryophytes in the form of dry-deposited gases and particles, and in wet deposition. Mosses are able to concentrate heavy metals to remarkably high concentrations owing to the high cation exchange capacity of their tissues, lack of protecting cuticle and large surface-to-weight ratio.

Bryophytes, particularly pleurocarpous mosses, bog moss (Sphagnum) and epiphytes, have been utilized in numerous studies in assessing and even in measuring atmospheric deposition rates of heavy metals (Tyler 1970, Manning & Feder 1980, Martin & Coughtrey 1982, Brown 1984). Bryophytes obtain nutrients from substances dissolved in ambient moisture. Funaria hygrometrica grow on burnt soil where the substrate has high pH and a high nutrient content, especially potash, cuprofile communities. Copper mosses chiefly Mielichhoferia, Scopelophila and Merceya species occur on the substrate rich in copper (Persson 1948). It has been suggested that some bryophytes could serve as a useful tool in determining the condition and character of the land (Watson, 1947). There is ample evidence that some bryophytes can be used as reliable indicators of pollution. The metals and other elements are accumulated to level in bryophytes which far exceed those in the surrounding environment because of following reasons:

1. They usually lack a protective cuticle and thickened epidermal cell walls, making their tissues easily permeable to water and minerals, including unwanted particles and metal ions.
2. Their tissues (cell wall constituents) have numerous negatively charged groups and act as cation exchangers. Also, there are groups with special affinity for heavy metal cations (chelating agents).
3. Their mineral nutrition is chiefly obtained from wet and dry deposition of particles and soluble salts. The substrate is of almost no importance in the mosses. The whole plant surface is able to absorb the material from air, soil and water (Ectohydric).
4. The formation of new biomass proceeds from the top of the current biomass, precluding any kind of direct contact or interaction with the soil or substrate.
5. There seem to be little or no translocation of heavy metals between adjacent segments, or from old to developing biomass, except in certain acrocarps. The shoots of higher plants take up metals from water or air and their roots take up metals from the soil or sediment, as well as from solution when they arecultured in it. Mosses accumulate metals from the air using their shoot or thallus, and macroalgae use their thallus to accumulate metals from water. Metal accumulation depends on both uptake into the tissue and leakage into the surrounding medium.

FACTORS AFFECTING THE SOLUBILITY AND AVAILABILITY OF METALS TO PLANTS

Partitioning of metals between solid and liquid phases in the soil is strongly affected by soil properties such as soil pH, organic matter content, soil solution ionic strength, Mn and Fe oxides, redox potential and the nature of sorbing soil surfaces. Factors that affect the solubility and plant availability of metals include their chemical characteristics, loading rate, pH, cation exchange capacity (CEC), redox potential, soil texture, clay content and organic matter content.

pH

Low pH increases the metal availability since the hydrogen ion has a higher affinity for negative charges on the colloids, thus competing with the metal ions of these sites, thus releasing metals. An increase in pH results in higher adsorption of Cd, Zn, and Cu to soil particles and reduces the uptake of Cd, Zn, and Pb by plants (Kuo et al. 1985). On other hand, acidification increases the metal absorption by plants through a reduction of metal adsorption to soil particles (Brown et al. 1994, Chaney et al. 1995, Huang and Cunningham 1996).

Redox Potential (EH)

The redox potential of the soil is a measure of the tendency of the soil solution to accept or donate electrons. With the decrease in redox potential, heavy metal ions are converted from insoluble to soluble forms, thus increasing bioavailability.

Cation Exchange Capacity (CEC)

The CEC of the soil is a measure of the ability of the soil to retain metal ions. The CEC increases with increasing clay content in the soil while the availability of the metal ions decreases. Modulating the CEC, results in increased or decreased availability of metals to plants. Soil Type The bioavailability of heavy metals in the soil also depends on the texture of the soil. A gradient of metal ion availability exists in varying soil types with the availability being lowest in clay soils, followed by clay loam, and finally loams and sand. Similarly, heavy metal concentrations in soil are also dependent on the soil order; Gleysols and Luvisols have the highest concentrations, followed by Brunisols and Podzols. A higher level of heavy metal can be retained in finetextured soils such as clay and clay loam compared with coarse textured soils such as sand, due to the low bioavailability of these metal ions, or reduced leaching as metals are bound to the soil matrix in fine-textured soils (Webber and Singh 1995). High organic matter content enhances the retention of the metals, drastically reducing the metal availability.

Chelates

Chelators are usually low molecular weight compounds such as sugars, organic acids, amino acids and phenolics that can change the metal speciation, and thus metal bioavailability. These chelators are synthesized by plants and can mobilize heavy metals such as Cu, Pb and Cd by formation of stable complexes. Addition of synthetic chelating agents such as ethelene diaminetetracetic acid (EDTA), ethylene glycoltetracetic acid (EGTA) to contaminated soils substantially increases the metal solubility in the soil (Salt et al. 1995, Cunningham and Ow 1996). In contrast, addition of Chelates to mineral nutrient solutions cause decreased metal accumulation as well as in the apparition of phytotoxicity symptoms (Srivastava and Appenroth, 1995). In contaminated soils, chelators application enhances the formation of metal-chelate complexes, reducing the sorption of metals to the soil particles.

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