Bioavailability of Zinc in Selected Plants and Their Associated Soils of Tirumala Region

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Abstract: ***Soil samples and plant organs from three native plant species, Datura metel L., Teprosia purpurea L. and Amaranthus viridis L. were collected from seshachalam forest of tirumala in order to determine the total and bioavailable zinc concentrations in soils and to assess the bioconcentration factor (BCF) and transport index (Ti) of zinc in the plants. Total zinc concentrations in soils (pH 7.3-8.7) where D. metel L., T. purpurea L. and A. viridis L. were collected, reached levels considered to be contaminated (162.76±22.13 , 241.81±69. and 203.74± 54.4 µg/g respectively). Bioavailable zinc ranged from 1.2 to5.2 µg/g. In the three plant species, zinc concentrations in leaves were significantly higher than in roots and stem. D. metel L. showed the highest concentration in its leaves (35.92±8.2) and higher values of BCF (0.2) and Ti (1.9), indicating that this species has a greater capacity to accumulate and translocate the metalloid to the leaf than do the other species.***

Keywords: Amaranthus viridis L., Datura metel L., Teprosia purpurea L., bioavailability, zinc

1. Introduction

Soils vary across the landscape, therefore each soil contains unique trace element concentrations based on its parent material and other soil-forming factors that may have added or removed these elements from the soil. High background concentrations of trace elements, whether natural or anthropogenic, could result in Mobilization and release into surface and subsurface waters and subsequent incorporation into the food chain. High organic matter (O.M.) content and cation exchange capacity (CEC) are some of the most important soil factors that determine the bioavailability of metals to plants [1]. Several studies document gradual increases in the trace element contents of agricultural and forested soils due to waste applications [2]-[4]. Trace elements, especially heavy metals, are considered to be one of the main sources of pollution in the environment, since they have a significant effect on its ecological quality. Human activities often mobilize and redistribute natural substances in the environment so much so that they can cause adverse effects [5]. Otherwise high levels of heavy metals in sediments, sludges and soils, and through transfer processes, also in groundwater and plants, may have a negative effect on animals and human health [6]. As a result, the number of environmental samples submitted to analyses in the frame of routine monitoring or risk and sustainability assessment studies is continuously growing.

Zn is an essential element to plant, but can be highly toxic at high concentrations. Recently, there has been an increase in research efforts on the use of higher plants to clean up contaminated soils with heavy metals. It has been proposed as a cost-effective, environmentally sustainable and in situ remediation technology for heavy metal contaminated sites [7]-[9]. So far, more than 400 plants have been reported as hyper accumulators of various heavy metals [10]. About 18 species of Zn hyper accumulators have been identified, and they accumulate higher concentration in shoots than roots. The occurrence of heavy metals in soils may be beneficial or toxic to the environment. Excess of metals may produce some common effects of individual metals on different plants (i.e. both macro- and micro flora). The biota may require some of these elements in trace quantities but at higher concentrations there may be toxicity problems. Metal toxicity in plants have been reported by various authors [11]-[15]. Generally, zinc is an essential element which belongs to Group-II of the periodic table. It acts as a plant nutrient [16]-[17] but at higher concentrations, it is toxic. Since it is assimilated early by plants, it can be highly phytotoxic. Growth inhibition is a general phenomenon associated with zinc toxicity [18]. Zinc is also a constituent of metalloenzyme or a cofactor for several enzymes such as anhydrases, dehydrogenases, oxidases and peroxidases [19] and plays an important role in regulating the nitrogen metabolism, cell multiplication, photosynthesis and auxin synthesis in plants [20]. It also plays an important role in the synthesis of nucleic acid and proteins and helps in the utilization of phosphorous and nitrogen during seed formation.

Datura metel L., Teprosia purpurea L. and Amaranthus viridis L. are important native plants having medicinal importance of seshachalam forest of tirumala. All these plants were used in the treatment of asthma or wheezing like symptoms and ulcers. The objectives of the study were to (1) Determine total and bioavailable zinc concentrations in different soils collected from seshachalam forest of tirumala, and (2) Assess the ability of native plant species that grow in these soils (D. metel L., T. purpurea L. and A. viridis L.) to accumulate Zinc.

2. Materials and Methods

2.1. Study Area

Native plant species and soil samples were collected from three distinct regions of seshachalam forest of tirumala. Tirumala the abode of Lord Venkateswara is located on seven hills known as Seshachalam Forest. These forests cover an area of 2675 hectors. These hill ranges have rugged topography with exposed rocks, steep slopes and rocky sub-soil. The climate of the study zone is hot and semi-arid. The maximum, minimum and mean temperatures are 44.2. 12.5 and 27.5^{o} C respectively. March, April and May experience highest temperatures while November, December and

January enjoy mild winters. The annual rainfall at Tirumala station ranges from 806 to 1559 mm with a mean of 1155 mm.

Figure 1: Seshachalam forest of Tirumala.

2.1.1. Collection and Preparation of Samples

Surface soil samples (0-30 cm depth) were collected in metal free polyethylene bags from the area adjacent to the plant roots. The pH was determined in aqueous extract 1:2. Organic matter was determined by a colorimetric method using $K_2Cr_2O_7$, H_2SO_4 and saccharose solution as standard solution. Total P was determined by elemental analysis. Electrical conductivity was measured by digital conductivity meter (Elico CM 180), with a cell constant value of 1.0. For the determination of total elements, soil samples were dried at 40^o C to constant weight, sieved to a particle size of 2 mm, digested with HNO_3: HCL: H_2O_2:HF (4:1:3:2) and evaporate to dryness to remove HF. Total Mn, Cu, Fe and Zn concentrations were determined by flame atomic absorption spectrometry (FAAS, Perkin Elmer). Bioavailable Zinc concentrations in the soil was measured by FAAS after extraction with di ethylene tri amine penta acetic acid (DTPA).

Three native plant species were collected in metal free polyethylene bags from seshachalam forest of tirumala. The collected plants were washed with running tap water in order to remove the adhering soil particles and then separated into leaves, stems and roots, dried at 60 ± 5^0 C until constant weight and then ground and sieved. Later samples were kept for ashing in a muffle furnace to remove the carbon content then digested with HNO_3: HCL: H_2O_2 (10:2:5) and Zn concentration was determined by FAAS. All results are expressed in dry matter. The bioconcentration factor (BCF) and transport index (Ti) of Zn to the leaf were calculated using the following equations

$$BCF = \frac{C_{Biota}}{C_{Soil}}$$

Where, C_{Biota} is the total metal concentration in leaf (µg/g) and C_{Soil} is the total metal concentration in soil (µg/g)

$$Ti = \frac{C_{Leaf}}{C_{Root}}$$

Where, C_{Leaf} is the concentration of metal in leaf (µg/g) and C_{Root} is the concentration of metal in root (µg/g)

3. Results and Discussion

The prepared soil and plant samples (Leaves, Stem and Roots) their physical, chemical characteristics, trace elements and bioavailable zinc concentrations have been analyzed by flame atomic absorption spectrometry and the results were tabulated in the Tables 1-2.

3.1. Physico-Chemical Characteristics

Physical characteristics like (pH, EC, TDS) and Chemical characteristics such as Organic carbon, Phosphorous and Potassium were studied, tabulated in the Table 1 and briefly discussed. The obtained results clearly shows that all the characteristics including physical and chemical and also Zinc (Total and bioavailable) concentrations were high in sampling site No.2. Slightly alkaline pH could be attributed to all the samples and in cases of alkalinity due to the dumping of solid wastes and food stuff from the domestic sources. The Electrical conductivity of soil showed maximum of 1.67 dS/m at sampling site No.2 and a minimum of 1.26 dS/m at sampling site No.1. The total dissolved solids in soil samples shows in the range between 0.73 mg/L to 0.94 mg/L.

Table 1: Main Physico-Chemical Characteristics, Total and Bioavailable Concentrations of Zinc (µg/g Dry Matter) In Soils

S. No.	Sampling Stations			
1			2	3
1	pH	7.3±0.03	8.7±0.01	7.8±0.05
2	EC	1.26±0.12	1.67±0.07	1.38±0.16
3	TDS	0.81±0.02	0.94±0.01	0.73±0.04
4	OC	17.0±3	17.5±2	17.1±5
5	P (%)	2.2±0.12	3.5±0.03	2.0±0.06
6	K (%)	0.05±0.02	0.08±0.05	0.02±0.01
7	Zinc	162.7±16.31	241.8±22.45	203.7±19.03
8	Bioavailable Zinc	1.28±0.33	5.21±1.67	1.31±0.81
9	Copper	1.73 ± 0.18	2.67 ± 0.72	2.08 ± 0.56
10	Iron	12.72 ± 9.39	16.13 ± 6.25	14.33 ± 8.71
11	Manganese	37.16 ± 14.33	36.68 ± 10.95	66.98 ± 23.11

Values are means ± standard deviations, n = 3

A similar concentration of organic carbon was found in all the soil samples. Whereas, high amounts of phosphorous was observed at sampling site No. 2 and negligible concentrations of potassium was found in all the samples. Zinc showed the high metal accumulation at sampling site No. 2 followed by copper and iron. Only manganese showed the maximum accumulation at sampling site No. 3.

Table 2: Zinc Concentrations In (µg/g), Bioconcentration Factor and Transport Index of Zinc to the Leaves

Plant species	Plant organs	Zinc (µg/g)	BCF	Ti
Datura metel L.	Leaves	35.9 ± 8.2	0.2	1.9
	Stem	33.2 ± 6.3		
	Root	18.2 ± 7.7		
Teprosia purpurea L.	Leaves	10.3 ± 3.6	0.04	1.3
	Stem	8.5 ± 3.0		
	Root	7.8 ± 2.6		
Amaranthus viridis L.	Leaves	13.0 ± 2.1	0.06	1.8
	Stem	8.8 ± 1.4		
	Root	7.0 ± 2.7		

Values are means ± standard deviations, n = 3

Figure 3.2 clearly represents that the leaves of all the plant species has a greater capacity to accumulate and translocate the metalloid. All the obtained elemental profile of the plant species was tabulated in the Table 2 and in Figure 2. Among all the plants Datura metel L. showed the high uptake of Zinc. Bioconcentration factor and transport index of soil and plant samples was investigated, the results showed that the all the plant species can be used as a hyper accumulator for Zinc as the transport index found to be greater than one. This study reveals that different plant species uptake different amount of trace elements especially zinc depending on the substrate concentration, nature, ageing as well as their soil type and climatic conditions. The obtained value shows that the concentrations of Zinc in plant organs differ significantly.

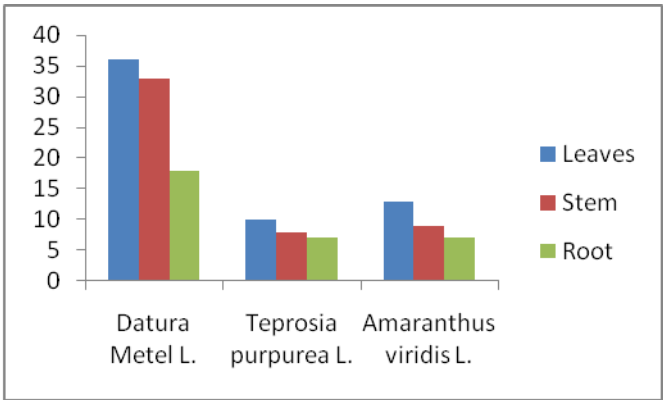

Figure 2: Concentrations of zinc (µg/g) in plant samples

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