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Phytoremediation Potential of *Canna indica* (Indian shot) for Cobalt and Zinc Contaminated Soil

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ABSTRACT

Rapid industrialization and urban expansion lead to the accumulation of toxic heavy metals in the soil and water system, such as Zinc (Zn) and Cobalt (Co). Traditional methods used for remediation of heavy metals from soil are expensive, unsustainable and generate a lot of secondary waste, which is difficult to manage. Phytoremediation, on the other hand, acts as an effective alternative to conventional methods, which use plants to extract and stabilize contaminants with a sustainable and cost-effective approach. This study examines the phytoremediation potential of Canna indica in removing heavy metal contaminants, i.e. zinc and cobalt, from the soil. A 45-day pot experiment has been conducted with three replicates per treatment, at concentrations of 2 mg/L and 5 mg/L for both metals under natural light conditions. Further, the accumulated concentration of both metals was measured using Atomic Absorption Spectroscopy (AAS). The data revealed discernible trends in the accumulation of both metals. Zinc is primarily accumulated in rhizomes, showing translocation rates of 80.82% at 2 mg/L and 41.79% at 5 mg/L, implying a phytostablization mechanism. On the contrary, Canna indica translocated Cobalt mainly to the aerial parts, with the very high translocation values of 305.61% at 2 mg/L and 160.78% at 5 mg/L, suggesting effective phytoextraction. Decreasing values of translocation as the concentration of contaminants rises may be due to phytotoxic stress. Thus, the findings support the dual efficiency of Canna indica both as a phytoextractor and phytostablizer for Cobalt and Zinc, respectively.

Keywords: Canna indica, Heavy Metal Pollution, Phytoremediation, Phytoextraction, Phytostabilization, Translocation Factor

I. INTRODUCTION

Heavy metal pollution in soil is a matter of serious environmental concern resulting from rapid industrialisation, urbanization, intensive application

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of chemicals in agricultural fields and improper disposal of solid waste. [1], [2]. Minimal quantity of heavy metals, such as zinc and cobalt, acts as micronutrients in the soil. However, the gradual accumulation of heavy metals in soil leads to a serious impact on the environment, plants, and humans due to their toxic and persistent nature [1], [3]. Leather tanning, chrome plating, batteries and glass manufacturing and several other industrial processes are the significant contributors to heavy metal pollution [4]. Heavy metals at elevated concentrations hinder the growth and activity of soil microorganisms. They may also enter the food chain and groundwater aquifers, depending on the mobility, and can cause serious health hazards [5], [6], [7]. Some metals, due to their mobility, can become bioavailable and restrict the growth of plants by causing disturbances in essential processes like photosynthesis and respiration. In humans, they cause serious health issues such as asthma, lung cancer, autoimmune diseases, memory loss, eye sight issues, brain damage, and kidney failure [8]. Conventional remediation techniques, which involve the use of physical and chemical methods such as soil excavation, chemical leaching, and thermal treatment, are often costly, have limited sustainability and generate additional waste [9], [10]. On the other hand, phytoremediation is the technique that uses the physiological and biochemical properties of living plants to remove contaminated areas where conventional techniques are not feasible to use. Thus, it is an effective alternative that is environmentally friendly and requires low installation and maintenance costs [11], [12], [13]. Phytoremediation involves various approaches that help to stabilize, extract, or degrade contaminants from soil and water. Phytoextraction involves the accumulation and relocation of heavy metals from soil to plant aerial parts, whereas phytostablization involves in-place inactivation of contaminants by lowering their mobility and bioavailability in the soil by utilising the plant root system [14], [15].

Canna indica (Fig 1), often used as an ornamental herb, also known as Indian shoot, belongs to the family Cannaceae [16], [17]. *Canna indica* has potential qualities like high biomass, fast growth, a wide range of stress tolerance and the ability to remove nutrients with visually appealing flowers, making it a potential candidate for the process of phytoremediation [18], [19]. Numerous studies have been conducted that show *Canna indica* effectiveness in eliminating pollutants from domestic wastewater as well as industrial effluents [20], [21]. *Canna indica* has a robust root system and strong tolerance to pollutants. Aerenchyma tissues in it facilitate oxygen transport to the rhizosphere, which enhances microbial activities [21]. However, biochemical defense mechanisms have not been fully explored, and most of the studies are based only on the initial morphophysiological evaluations [22].

This study examines the phytoremediation potential of *Canna indica* in removing heavy metal contaminants, i.e. zinc and cobalt, from the soil. A 45-day pot experiment has been conducted, which involves three replicates of each treatment at two different concentrations of 2 mg/L and 5 mg/L for both metals. Metal accumulation in the shoots and rhizomes of *Canna indica* has been assessed using Atomic Absorption Spectroscopy (AAS), which reveals the dual nature of *Canna indica* both as a phytoextractor and phytostabilizer for cobalt and zinc, respectively, making it a suitable candidate for reducing heavy metal pollution in soil.



Fig 1: *Canna indica*

II. METHODS AND MATERIALS

Samples of *Canna indica* consisting of two flowers attached to a roughly 25 cm long stem along with two large leaves, were collected for herbarium preparation in April 2025 from Dadroli Shahpur, Himachal Pradesh, India (Latitude: 32.225142°, Longitude: 76.155409°). The plant was identified by CSIR-Institute of Himalayan Bioresources Technology (IHBT) in Palampur, Himachal Pradesh. A voucher specimen was deposited in the department with the accession number PLP 24668.

Rhizomes of *Canna indica*, approximately uniform in size and weight, were collected from a shady, moist location in Dadroli, Shahpur, Himachal Pradesh, India. Rhizomes are then carefully packed in the sterile sample bags and sent to the laboratory for pot cultivation. Fertile soil free from stones and debris has been collected from the nearby agricultural field. All fifteen pots (4 inches in diameter) are then filled with the prepared soil. Rhizomes are planted in the pots, one in each, with the same depth and orientation and placed under the natural sunlight. Two different heavy metals (Zinc and Cobalt) stock solution has been prepared for this experiment. Stock solution for Zinc has been prepared using Zinc sulfate heptahydrate while stock solution for Cobalt has been prepared using Cobalt (II) chloride hexahydrate at the concentration of 2 mg/L and 5 mg/L for each metal. Thus, in this manner, four treatments have been prepared and labelled carefully for further application. All the pots have been sealed at the base using adhesive tapes and plastic sheets to prevent leaching of metals, and a single application of 50 ml of each solution has been provided to the respective pots (as labelled) on the day of planting. Pots are then monitored closely and provided with appropriate water and sunlight.

After 45 days, the plants were harvested from the pots and washed thoroughly in tap water (Fig 2), followed by distilled water to remove any adhering soil particles. After washing, the plants are oven-dried at 80° C for 24 hours. After complete moisture loss, the rhizomes and shoots of the plants have been separated (while the roots have been discarded) and ground with pestle and mortar into a fine powder and stored in labelled sample bags. For sample preparation, 0.5 g of each powdered sample has been treated with concentrated nitric acid and hydrochloric acid in a ratio of 3:1 (15 mL and 5 mL, respectively). The mixture was heated at 110° C until a clear solution was obtained [19]. After digestion with acid, samples are allowed to rest at room temperature for the next 24 hours and then filtered using Whatman no. 42 filter paper and stored at room temperature in labelled glass bottles. Atomic Absorption Spectroscopy is performed to quantify the accumulated concentration of zinc and cobalt in the rhizome and shoots of *Canna indica* after 45 days of treatment, for which the prepared samples have been sent to the Central Instrumentation Facility, Central University of Jammu, Jammu and Kashmir, India.

To analyse the phytoremediation potential of *Canna indica,* the translocation factor has been calculated, which provides insights into the plant ability to transfer heavy metals from roots to above-ground parts [23]. Using the formula [20]-

$$TF = \frac{C_{aerial\ part}}{C_{belowground\ part}}$$

Where C_{aerial} parts and $C_{belowground}$ parts denote metal concentration (mg/kg) in the shoot and rhizome, respectively.



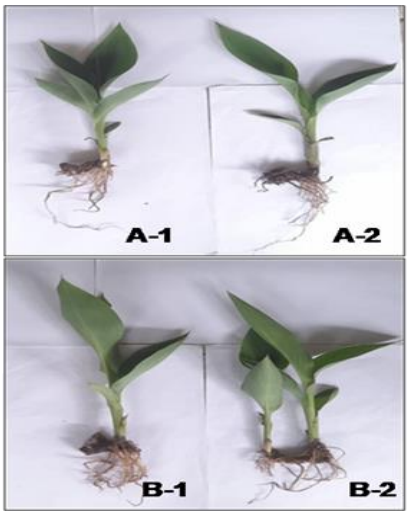


Fig 2: Growth of *Canna indica* on the day of harvesting (after 45 days of planting)

III.RESULT AND DISCUSSION

Table 1 presents the results of the analysis by Atomic Absorption Spectroscopy (AAS), which show the concentration-dependent translocation of zinc and cobalt in the shoot and rhizome of *Canna indica*. Based on the accumulated concentrations of both metals, TF has been calculated, indicating the phytoremediation ability of *Canna indica* for Cobalt and Zinc.

Table 1. Concentration of heavy metals accumulated in *Canna indica* after 45 days of exposure.

Heavy Metal	Concentration (mg/L)	Shoot (mg/kg)	Rhizome (mg/kg)	Translocation Factor (TF)	Translocation Percentage (%)
Zinc	2	0.7675	0.9496	0.8082	80.82
	5	0.6055	1.4488	0.4179	41.79
Cobalt	2	0.3322	0.1087	3.0561	305.61
	5	0.1275	0.0793	1.6078	160.78

**TF>1 favours phytoextraction [19]*

***TF<1 favours phytostabilisation [20]*

A. *Zinc Accumulation and Translocation in Canna indica*

AAS data suggest that zinc can be effectively phytosabilized in the rhizomes of *Canna indica.* TF values less than 1 show limited mobilisation of zinc from the rhizome to the shoot of the plant. This can also be confirmed by looking at the higher zinc accumulation in the rhizomes as compared to the above-ground parts. At the concentration of 2 mg/L, 0.7675 mg/kg and 0.9496 mg/kg of zinc have been accumulated in the shoot and rhizome, respectively. Similarly, at the concentration of 5 mg/L, 0.6055 mg/kg and 1.4488 mg/kg of zinc have been accumulated in the shoot and rhizome, respectively. At both the concentration lower levels of Zinc accumulation have been recorded in the shoot portion. However, at higher concentration, more zinc has been accumulated in rhizomes compared to lower concentrations, which shows concentration-dependent translocation. Translocation factor values of 0.8082 and 0.4179 have been recorded at the concentrations of 2 mg/L and 5 mg/L, respectively. Lower TF value at higher concentration of zinc may suggest restricted mobilisation due to phytotoxic effect.

B. *Cobalt Accumulation and Translocation in Canna indica*

In contrast to the case of zinc, AAS data suggest effective translocation of cobalt from rhizomes to the shoots by the process of phytoextraction. TF values above one show high translocation efficiency of cobalt, which can be validated further by the data provided in Table 1, which shows higher cobalt accumulation in shoots as compared to rhizome. At the

concentration of 2 mg/L, 0.3322 mg/kg and 0.1087 mg/kg of cobalt concentration have been recorded in shoots and rhizomes, respectively. Further, at the higher concentration of 5 mg/L, 0.1275 mg/kg and 0.0793 mg/kg of cobalt have been accumulated in the shoot and rhizome, respectively. As discussed earlier, this data shows TF values above one, i.e. 3.0561 and 1.6078 at 2 mg/L and 5 mg/L/, respectively. Again, lower TF values at higher concentration may be due to the phytotoxic effect of cobalt on the plant. Thus, this data supports the idea of *Canna indica* as an effective phytoremediator.

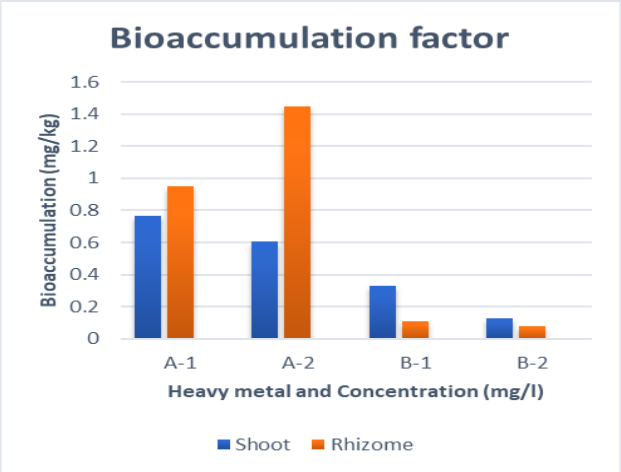


Fig 3: Bioaccumulation of zinc and cobalt in the shoots and rhizomes of *Canna indica* at varying concentrations (A-1: Zn 2 mg/L, A-2: Zn 5 mg/L, B-1: Co 2 mg/L, B-2: Co 5 mg/L).

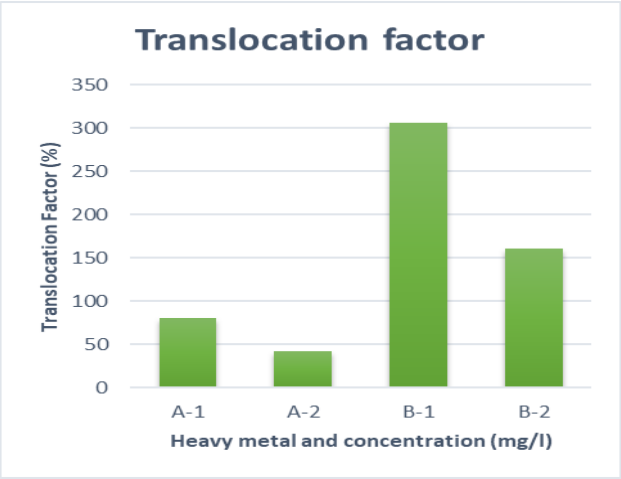


Fig 4: Translocation factor (%) of zinc and cobalt in *Canna indica* under different concentration treatments (A-1: Zn 2 mg/L, A-2: Zn 5 mg/L, B-1: Co 2 mg/L, B-2: Co 5 mg/L).

Figures 3 and 4 represent bioaccumulation and translocation of cobalt and zinc in *Canna indica*. This data shows higher values of bioaccumulation in the case of zinc as compared to cobalt, which emphasises the influence of metal type and concentration on uptake. Zinc is predominantly retained in the rhizome in contrast to cobalt, which has greater accumulation in the above-ground parts of the plant. This reveals lower translocation efficiency of zinc, which is consistent with the findings of [19], reports higher accumulation of zinc in below-ground parts due to its low mobility and strong rhizosphere binding. These findings are further supported by the TF values of zinc, which are lower than one at both concentrations (0.8082 and 0.4179) and support the idea of phytostabilisation of zinc by *Canna indica.*

However, in the case of cobalt, higher translocation efficiency with the TF values above 1 at both concentrations (3.0561 and 1.6078) has been recorded, which is also supported by the study conducted by [24], which reported enhanced shoot accumulation of cobalt. It has also been noted that the concentration at 2 mg/L zinc TF values reaches nearly one (0.8082), which is consistent with the findings of [20], suggesting zinc can also be taken up by roots and transferred to the shoots at a moderate level.

Hence, these distinct patterns support the idea of *Canna indica* as a dual performer, both as a phytostabilizer and phytoextractor for zinc and cobalt, respectively. These findings support the potential of *Canna indica* as a phytoremediator.

IV. CONCLUSION

This study analyses the phytoremediation potential of *Canna indica* using zinc and cobalt at two different concentrations with the help of Atomic Absorption Spectroscopy. Zinc mainly accumulated in the rhizome with TF values below one, while cobalt accumulation in the shoots occurs with TF values above one. These results demonstrate *Canna indica* both as a zinc phytostabliser and a cobalt

hyperaccumulator. Despite this, these results are limited to short-term, pot experiments and require further study at a broader level. In summary, *Canna indica* is considered a cost-effective and sustainable alternative for reducing heavy metal pollution in soil.

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VI. AUTHOR CONTRIBUTION

Munish Sharma (ORCID: 0000-0001-9953-3154) conceptualized the research idea and approved the research methodology, while Tamanna Sharma (ORCID: 0009-0008-6424-3710) conducted all experiments, analyzed the data, and drafted the initial manuscript. Both authors reviewed and approved the final version for submission.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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