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# Ornamental Plant Species forApplication inPhytoremediation of Metal Contaminated Soils

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**Abstract**

Phytoremediation makes use of selected plant species which can help in removing toxic pollutants from soil to enhance the quality of ecosystem. Phytoextraction (sequestering contaminants by plants in their harvestable parts) and Phyto stabilization (*insitu* or site immobization/stabilization of contaminants) are two of the important phytoremediation approaches besides phytovolatilization (conversion of absorbed metal to volatile and less toxic metal), and phytotransformation. In present study the suitability of some ornamental plant species for their phytoremediation ability was explored based on pot culture study in greenhouse for 45 days under controlled conditions. Ornamentals selected for the study were *Tagetes erecta, Dracaena braunii,Canna indica,Sansevieria trifasciata* and *Nephrolepis exaltata.*The plants were grown in pots with soils each treated with heavy metal ( Cr, Zn, Ni or Fe) separately, at two concentrations, while controls were maintained without any metal addition. Changes in biomass, appearance of visible phytotoxicity and metal accumulation in plant tissues both aboveground and belowground were used to find the tolerant and potential candidate for phytoremediation. Metal concentration was measured by Atomic absorption spectroscopy (AAS). Plants were finally selected on the basis of tolerance index and metal accumulated (mg/plant) in their tissues.

## 1. Introduction

Metal contamination of soils has become a commonly prevailing problem due to various metal containing industrial discharges, mine tailings, agrochemicals and atmospheric depositions (Massa *et al*., 2010). Elements with densities > 5 g cm$^{-3}$ are categorized as heavy metals and environmental pollutants. Some metals ( Ni, Fe, Zn, Co, Mn, Mg, Cu) are required by plants as well as by animals in trace amounts for their normal growth and metabolism are micronutrients, but become toxic beyond a threshold level, while there are others like Cr, As, Pb, Hg that are non-essential and are toxic and reactive at all concentrations (Reeves *et al*., 2000). A major problem with heavy metals is their non- degradability and accumulation through food chain. Once the heavy metal enters the soil , it persists there for years posing problems to environment (Meirezky *et al*., 2004).Contamination of land can also result in pollution of nearby surface waters as well as ground water and pose risks and hazards to humans and the ecosystems through ingestion or through the food chain, and reduction in land usability for agricultural production causing food insecurity(Schmidt, 2003). Clean-up of such metal contaminated soils is very important and challenging and various techniques involving physical and chemical methods like soil washing or electro kinetics have been cost intensive and unsustainable due to adverse effects on soil quality (Mulligan *et al*.,2001). Phytoremediation has emerged as a modern eco-friendly and cost-effective plant-based approach to decontaminate such soils, which also restores the soil composition without damaging other components of ecosystem (Willey, 2007; Butcher, 2009).

Phytoremediation makes use of selected plant species which can help in removing toxic pollutants from soil to enhance the quality of ecosystem (Mir *et al*.,2017). Phytoextraction(sequestering contaminants by plants in their harvestable parts) and Phyto stabilization (*insitu* or site immobization/stabilization of contaminants) are two of the important phytoremediation approaches besides phytovolatilization (conversion of absorbed metal to volatile and less toxic metal), and phytotransformation *i.e.* conversion of organic pollutants using soil microbes in rhizosphere(Blaylock *et al*., 2000; Pierzynski *et al*., 2002).To make the approach sustainable selection of plant species play the most significant role. Hyperaccumulator plant species that have high metal accumulation capability, such as *Thlaspicaerulescens*, a Zn and Cd hyperaccumulator (Brown *et al*., 1994), *Corydalis davidii,* Zn hyperaccumulator (Lin *et al*.,2012) and *Alyssum murale* a very efficient Ni hyperaccumulator (Bani *et al*., 2007) have been tried on field to clean up metal contaminated sites. Although hyperaccumulation of metal is a rare phenomenon and plant species with this capability are known to be found and discovered near areas having high heavy metal concentrations (Sheoran *et al*., 2011).Only 0.2% of angiosperms have been classified as hyperaccumulators (Kramer,2010) and several fern species like *Salvinia* ,an aquatic fern has been recommended for their potential use in phytoremediation of heavy metals (Dhir, 2009). Hyperaccumulators belong to around 101 families including Asteraceae, Brassicaceae, Fabaceae, Poaceae, Euphobiaceaeetc. with Brassicaceae being richest in hyperaccumulators including *Alyssum* and *Thlaspi* (Verbruggen *et al*., 2009). However, using hyperaccumulators has its own limitations in phytoremediation as these plant species are slow growing and too small in size. Therefore, more attention is given to select plants with good biomass, profuse root system, and fast growth.

Some of the most commonly used hyperaccumulator species like *Brassica juncea*, *Brassica napus, Sorghum vulgare, Zea mays, Medicago sativa* and *Helianthus annuus* that have been reported in earlier studies to accumulate high concentration of metals like Pb, Cr, Cd, Cu, Ni, Zn, Cs, Sr and Hg (Salt *et al*. 1998) are edible plants and hence, have implications on human health, risk of introduction of the contaminants into the food chain via consumption by wildlife or grazing livestock is also a challenge when grasses or edible plants are used for phytoremediation (Kvesitadze *et al*., 2006).In view of these challenging issues and criteria to be considered in phytoremediation, ornamental plant species seem to be ideal if they show metal removing capability. The ornamental plants accumulating metals in non-edible biomass will not only provide an environmentally sound alternative for phytoremediation, but also add to the aesthetics of the degraded site. It is now evident that the clean-up strategy must be cost effective, safe and lead to stabilization of the environment (Allen, 2019).

The present study was therefore, conducted to screen selected ornamental plant species with good biomass to test their metal tolerance index and capability to remove the metals at moderate and high concentrations with a view to use them for phytoremediation.

## 2. Material and Methods

### 2.1 Plant species:

Plant species selected for the present study included *Dracaena braunii*, *Sansevieriatrifasciata*, *Tageteserecta*, *Nephrolepisexaltata* and *Canna indica*, all of which are commonly grown as ornamental plants. *Dracaenabraunii* (family Asparagaceae)also known as *Dracaena sanderiana,* is a flowering plant commonly known as luckybamboo, can grow well in both soil and water. *Tageteserecta* (family Asteraceae or Compositae), commonly known as marigold is both annual and perennial in nature. *Sansevieriatrifasciata* (family Asparagaceae), is an evergreen perennial plant which spreads by means of rhizome and commonly known as Snake plant. *Canna indica* (family Cannaceae), known as African arrowroot or Indian Shot, is a perennial plant, which forms branched rhizomes and bears beautiful large flowers. *Nephrolepisexaltata* (family Lomariopsidaceae) known as sword fern is a perennial herbaceous plant.

### 2.2 Metal treatments:

The present study was designed with a view to screen the pants for their future application in remediation of soils near electroplating industry, which is contaminated with Cr, Ni, Zn and Fe. Young plants of approximately same age, height and biomass were obtained from local nursery at New Delhi. Pot culture experiments were carried out for 45days in the month of February and March (2017) using plastic pots under controlled conditions in greenhouse at university campus in triplicates. A total of 135 plastic pots (5 plant species x 4 metals x 2 concentrations each x 3 replicates + 5 controls x 3 replicates) were taken and were kept in shade. Garden soil (pH 7.2, EC 0.42 ms/cm and TOC 0.2%) served as control while four heavy metals Cr ($K_2Cr_2O_7$) , Zn ( $ZnSO_4 \cdot 7H_2O$), Fe ($FeSO_4.7H_2O$ ) and Ni

($NiSO_4.6H_2O$), were added to garden soil in calculated quantities serving as two levels (moderate and high) of metal contamination. Metal salts were evenly mixed with dried soil and kept in pots separately with 500, 1000 mg of chromium, zinc, and iron per kg soil, respectively and 100 and 300 mg of nickel per kg soil. Each pot contained5kg soil. Plants were watered as per requirement with normal tap water. Plants were harvested after 45 days of study. Concentration of metals taken for soil treatment was decided based on available relevant literature.

### 2.3 Metal tolerance and bioconcentration:

Visual symptoms of phytotoxicity to the four metals were recorded after transplanting the plants. Fresh and dry biomass of complete were determined at 0 day and 45days. At the end of the study (45days), all plants were harvested, washed in deionized water. Fresh weight was taken after soaking off the water from the plants using blotting paper. The plants were then oven dried at 65 °C for 72 hours and dry biomass was measured using an electronic balance.

Tolerance index (TI)was calculated following Wilkins (1978) as:
TI(%) =(Plant Biomass in metal contaminated soil / Plant Biomass in control) X100

Relative water content was measured following (Chen *et al*., 2009) as:
Water content (%) = (Fresh weight - Dry weight/ Fresh weight) X100
Relative water content (RWC %) = (Water content in plant under treatment/ Water content in plant under control) X100
Total metal uptake (mg/plant) = Metal concentration in the plant X Total dry weight
Bioconcentration factor (BF)for each metal was calculated following (Yoon *et al*.,2006) as:
BF= Concentration of the heavy metal in plant/ Concentration of the heavy metal in soil

### 2.4 Metal analysis:

Dried samples (both above ground and below ground parts) of all plants were acid digested. Finely crushed dried plant samples(1 g each) were taken in digestion tubes separately and 1 ml of distilled water, 2 ml mixture of nitric acid (60%) and perchloric acid (60%) ($HNO_3$:$HClO_4$) (1:1 v/v ) and 5 ml sulphuric acid were added to each tube and refluxed at 200 ºC for 30 minutes in a fume-hood chamber. After acid digestion, samples were cooled and filtered through Whatman 42 filter paper and diluted with deionized water to 50 ml (Jin *et al*., 1999; Otchere, 2003). The filtrate was then analyzed for heavy metal (Cr, Ni, Zn and Fe) using Atomic. absorption spectroscopy (AAS-Agilent 280 FS AA). Final concentration of heavy metals in plant tissues was calculated as parts per million (ppm).

Data was represented as mean ± S.D and was statistically analyzed for testingthe significance of differences by comparing means of treatments with means of control using one-way ANOVA.

## 3. Results and Discussion

### 3.1. Metal Tolerance and Biomass:

Some visible symptoms of toxicities when plants were exposed to high concentrations of heavy metals especially Cr were chlorosis, necrosis and interveinal yellowing, particularly in response to Cr contamination in the soil. Effect on biomass and growth of all test plant species was found to be different for different metals and at different concentrations. Biomass of plants reflected overall effect of heavy metals on health and growth of the plants.

A significant ($p<0.05$) decline in biomass (dry weight) was recorded at both 500 and 1000µg $g^{-1}$ concentration of Cr in all plant species except for *S. trifasciata* which showed a slight increase in biomass at 500µg $g^{-1}$Cr(28.44g) as compared to that in control( 27.1g). *S. trifasciata* was found to have increase in its biomass at both concentrations of Zn, Ni and Fe as compared to control. In all the plant species, biomass was found to be the lowest when plants were exposed to higher concentrations of metals. Stunted growth, chlorosis and necrotic tips were observed in all plant species, particularly at the high concentration of the metals. A significant decline in biomass of *T. erecta* was recorded at higher concentration of all the four metals, indicating its sensitivity and low tolerance towards high concentrations of these metals. On the other hand, *Sansevieria* showed a significant ($p<0.05$) increase in biomass when exposed to high concentrations of these metals. A significant increase ($p<0.05$) in biomass was observed in presence of Ni, Fe and Zn by *Nephrolepis* and *Canna* also. However, *Dracaena* was found to have significantly reduced biomass at high concentrations of Zn and Fe (Table. 1)

Table 1. Dry biomass of plants (g) in response to different metals (Values are presented as mean ±S.D;**represents significant differences between treatment and respective control at $p<0.001$, and * $p<0.05$)

| **Plants** | **Control** | **Cr** | | **Zn** | | **Ni** | | **Fe** | |
|---|---|---|---|---|---|---|---|---|---|
| | **0** | **500 ppm** | **1000 ppm** | **500 ppm** | **1000 ppm** | **100 ppm** | **300 ppm** | **500 ppm** | **1000 ppm** |
| *Tagetes erecta* | 10.12± 0.33 | 3.32 ± 0.20** | 1.71 ± 0.07** | 9.87± 0.52 | 7.28± 0.02** | 10.01± 0.14 | 8.84± 0.10** | 10.54 ± 0.15 | 8.13± 0.22** |
| *Dracaena braunii* | 10.81 ± 0.89 | 6.93± 0.81* | 3.60 ± 0.64* | 11.46 ± 0.59 | 8.30 ± 0.34* | 12.92± 0.21** | 10.31 ± 0.14 | 10.92 ± 0.39 | 8.38 ± 0.31* |
| *Nephrolepis exaltata* | 24.81 ± 0.57 | 15.85± 0.66** | 9.62 ± 0.78** | 26.38 ± 0.75 | 21.73± 0.60* | 25.28± 0.43 | 27.11± 0.36* | 28.17± 0.17** | 21.76± 0.45** |
| *Canna indica* | 24.62 ± 0.79 | 10.96± 0.78** | 8.12 ± 0.37** | 29.66 ± 0.51** | 26.02 ± 0.32 | 27.33± 0.14** | 28.75± 0.21** | 27.06 ± 0.50* | 25.10 ± 0.27 |
| *Sansevieria trifasciata* | 35.88 ± 1.10 | 37.49 ± 0.09 | 19.64± 0.83** | 42.62± 0.33** | 46.17± 0.41** | 40.08±. 24** | 42.67± 0.20** | 39.62± 0.29* | 35.49 ±0.48 |

Tolerance to stress can be assessed by taking either biomass as an indicator or by observing any visible signs of phytotoxicity. Mostly the essential metals in higher concentration led to decline in dry biomass of the plants, which could be due to toxic effects on metabolism and decrease in photosynthesis beyond a threshold concentration (Younis *et al*., 2015; Ishtiaq and Mahmood, 2011;El-Enany *et al*., 2000). Sharp decline in biomass of most species due to Cr, a non-essential heavy metal, is due to increased permeability of tissues leading to breakdown of tolerance mechanisms in plants (Sen and Mondel,1987).

### 3.2. Relative water content (RWC):

Another parameter called relative water content, which is the water content in the plant biomass under a treatment relative to that in respective control taken as 100, is related to metal tolerance of the species. A significant ($p<0.05$) decline in relative water content is seen at both concentrations of Cr in all test plant species, with RWC values ranging from 69 to 95 as compared to respective controls, except that for Canna (105) and *Sansevieria* (100.39) at 500 ppm Cr. In response to Zn and Ni all the species other than *Tagetes,* showed RWC>100, and significant ($p<0.05$) in response to Fe, all the five species showed RWC values exceeding 100 (Table 2). Reduction in RWC indicates that stress is induced by high concentration of a metal. In order to deal with the metal stress, plants tend to accumulate more water that may be correlated to metal ion dilution effect, and the species with higher RWC are found to show greater tolerance to the metal. Increase in RWC and tolerance response are in line with some previous findings on seedlings of *Jatropha curcas* (Gao *et al*., 2010).

### 3.3. Tolerance index (TI):

Tolerance in dexmeasured as the percentage of ratio of biomass of treated plants to that of biomass of control plants is shown in Table 3. Tolerance Index of Tagetes*erecta* was significantly ($p<0.001$) very low for Cr(16.9-32.8%). Amongst other species, *Dracaena braunii*, *Nephrolepis exaltata* and *Canna indica*, showed 32.9-64.1% TI to the two metal concentrations of Cr. It was only *Sansevieria trifasciata,* which showed TI of 104.6% at 500 $\mu g\ g^{-1}$

Cr concentration. The general decline in tolerance index of the plant species to Cr may be attributed to its non-essential and toxic nature.

For plants grown with Zn treatment, the TI was much higher. Even *T. erecta* showed 71.9-97.5% TI. All other species tended to utilize the lower Zn concentration of $500 \mu g\ g^{-1}$ as a useful metal showing higher biomass and as a result, TI > 100 (106-120). *S. trifasciata* was the only species that showed significant increase ($p<0.001$) in TI 128.76% even at1000 $\mu g\ g^{-1}$ Zn. All the species showed good and significant ($p<0.05$) tolerance (87-118%) to 100 and $300 \mu g\ g^{-1}$ Ni concentrations in soil. Likewise, tolerance index of all the five species was moderate to high (77.5-113.5%) in response to 500 and $1000 \mu g\ g^{-1}$Fe in case of *T. erecta, D. braunii* and *N. exaltata*, whereas *C. indica*and *S. trifasciata* showed high TI. Tolerance index>100% indicates a significant ($p<0.05$) increase in biomass of plants in response to Zn, Ni and Fe even at moderate or even at high concentrations, indicating that these essential metals are utilized by the plants for their normal metabolism and growth, which is a positive indication for their potential use in bioremediation of soils contaminated with these metals. Amongst all the five species, TI value *S. trifasciata* for all concentrations and metals found to be the highest, which shows metal tolerant nature of this plant.

Table 2. Tolerance index (%) of the plant species to varying concentrations of the metals (Values are presented as mean (±S.D), ;**represents significant differences between treatment and respective control at $p<0.001$, and * $p<0.05$)

| ***Plants*** | **Cr** | | **Zn** | | **Ni** | | **Fe** | |
|---|---|---|---|---|---|---|---|---|
| | **500 ppm** | **1000 ppm** | **500 ppm** | **1000 ppm** | **100ppm** | **300 ppm** | **500 ppm** | **1000 ppm** |
| *Tagetes erecta* | 32.8± 2.41** | 16.89± 1.17** | 97.53± 5.83 | 71.94± 2.34** | 98.91± 4.24 | 87.35± 1.99* | 104.15± 2.64* | 80.34± 0.87** |
| *Dracaena braunii* | 64.11± 4.20** | 33.3± 4.72** | 106.01± 14.87 | 76.78± 8.66 | 119.52± 11.88* | 95.37± 7.14 | 101.02± 11.79 | 77.52± 9.59* |
| *Nephrolepis exaltata* | 63.89± 1.35** | 38.77± 2.52** | 106.33± 2.72* | 82.37± 2.98* | 101.89± 1.73 | 109.27± 1.89* | 113.53± 2.89** | 87.71± 0.48** |
| *Canna indica* | 44.51± 2.19** | 32.98± 2.37** | 120.47± 2.45** | 87.73± 4.46* | 111.01± 3.36* | 105.2± 4.65* | 109.91± 3.31* | 101.95± 4.36 |
| *Sansevieria trifasciata* | 104.49± 3.38 | 52.39± 3.96** | 118.78± 4.52** | 128.68± 3.92** | 111.71± 3.14* | 118.92± 3.11** | 110.42± 4.09* | 98.91± 1.78 |

Table 3. Relative water content (% of control) of the test plant species in response to varying concentrations of the metals (Values are presented as mean (±S.D), ;**represents significant differences between treatment and respective control taken as 100; at $p<0.001$, and * $p<0.05$)

| ***Plants*** | **Cr** | | **Zn** | | **Ni** | | **Fe** | |
|---|---|---|---|---|---|---|---|---|
| | **500 ppm** | **1000 ppm** | **500 ppm** | **1000 ppm** | **100ppm** | **300 ppm** | **500 ppm** | **1000 ppm** |
| *Tagetes erecta* | 94.46± 12.14 | 89.25± 4.13 | 97.17± 7.50 | 96.20± 2.81 | 99.03± 1.61 | 93.29± 3.55* | 111.81± 2.43* | 100.76± 5.42 |
| *Dracaena braunii* | 77.95± 8.62* | 93.98± 6.83 | 104.68± 6.05 | 102.62± 9.22 | 104.39± 6.05 | 104.37± 6.03 | 128.86± 5.13** | 122.91± 5.66* |
| *Nephrolepis exaltata* | 83.25± 6.04* | 69.49± 2.61** | 107.14± 0.31* | 103.74± 3.29 | 101.15± 4.54 | 102.21± 4.24 | 102.96± 1.00 | 102.96± 15.41 |
| *Canna indica* | 104.90± 7.56 | 93.67± 9.50 | 104.41± 2.60 | 106.83± 1.75* | 100.34± 3.39 | 100.89± 3.82 | 104.10± 4.62 | 100.52± 2.34 |
| *Sansevieria trifasciata* | 100.39± 1.19 | 95.31± 2.28* | 100.62± 1.02 | 103.12± 1.89* | 100.57± 3.39 | 104.06± 3.82 | 131.05± 0.99** | 131.48± 1.91** |

### 3.4. Metal accumulation:

Metal accumulation (mg/plant) by the five ornamental plant species were highly variable as shown in Fig. 1. Uptake of Cr by plants did not vary significantly between the metal dose but was significant ($p <0.001$) as compared to respective controls (Fig. 1a) . *Sansevieria* showed highest uptake (14.24 mg/ plant) where *Tagetes*showedminimum uptake (2 mg/ plant). Uptake of Cr by *Canna* and *Nephrolepis* were almost similar (10-11mg/plant). Despite being non-essential, Cr uptake was quite high in *Canna*, *Nephrolepis* and *Sansevieria,*.

Zn accumulation was also lower in *Tagetes* and *Dracaena* (2.8-4mg/plant) *,* while highest uptake of Zn was found in *Nephrolepis* (16.63 mg/plant) followed by *Sansieveria* (15.25 mg/ plant) and *Canna* (10.44mg/plant). Uptake of Zn by the plants was significant ($p<0.001$) as compared to control and also dose dependent, showing higher uptake at higher metal dose (Fig. 1b).

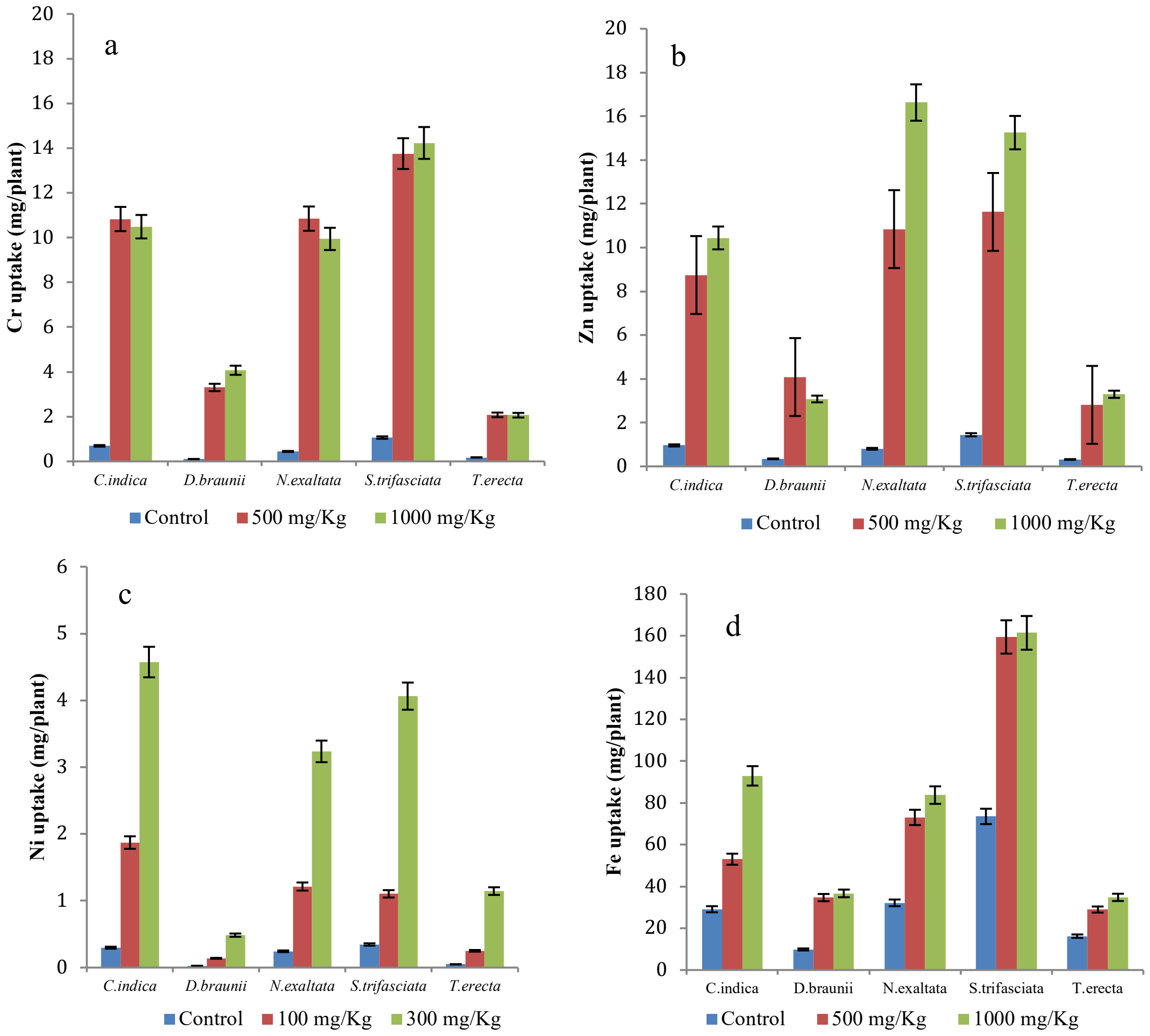

Fig.-1. Metal accumulation (mg/plant) by the five ornamental plant species with different treatments.

Similar trend of accumulation of Ni was also observed in all the plant species where accumulation was found to be dose dependent (Fig.1c). Higher and significant ($p<0.001$) accumulation of Ni was observed in the plants at 300µg $g^{-1}$ Ni concentrations with *Canna* showing the maximum Ni uptake (4.57 mg/plant) followed by *Sansevieria*(4.06 mg/ plant) and *Nephrolepis* (3.24 mg / plant) and *Dracaena* showed least uptake of Ni (0.14 mg /plant). Amongst all metals maximum uptake was recorded for Fe in all test plant species (Fig.1d), with *Sansevieria* showing maximum and significant ($p<0.001$)uptake (159 -161 mg/plant) at the two concentrations, followed by *Canna* (92.95 mg/plant) and *Nephrolepis* (83.74 mg per plant) at 1000µg $g^{-1}$. The minimum uptake of Fe was observed in *Tagetes* (34.77mg/plant).

Our results indicated that the accumulation of all heavy metals investigated in these ornamental plant species was significantly ($p<0.001$) higher in comparison to their respective control plants grown in an un-amended soil showing their ability to accumulate a considerable amount of heavy metals. Thus, all plants seem to be capable of remediating the metal contaminated soil to some extent. Zn, Fe and Ni are all essential elements required by plants for their normal growth and metabolism. These elements are known to have important functions as cofactors of enzymes, in photosynthesis, nitrogen fixation, and structural ions for TFs etc. (Hänsch and Mendel 2009). According to certain studies 500 µg $g^{-1}$ of Fe in plant tissue is considered as the threshold level, above which concentration iron would show toxic effects in plants (Istvan and Benton, 1997). The study shows that test plant species are tolerant to Fe in spite of absorbing a significant amount of iron from soil. The toxic level of Zn is found to be more than 230 µg $g^{-1}$ in plant tissues according to some studies (Borkert *et al*., 1998; Long *et al*., 2003). Thus, several parameters are to be taken into account while selecting plants for phytoremediation. For phytoremediation, plants need to accumulate high concentrations of metals, be able to translocate metals from root to shoot but at the same time should be able to produce a high biomass without showing phytotoxicities. However, according to many researchers phytoremediation potential of a plant should not only depend on its ability to accumulate target metal in its tissue, as plants with low dry biomass results in less removal of metal from soil in spite of having high concentration of elements in its tissues (Robinson *et al*., 1997; Lasat 2000). Hence, plant with good dry biomass should be considered for final selection as the candidate for phytoremediation.

## 4. Bioconcentration factor (BCF):

Bioconcentration factor of a species, which is the ratio of concentration of heavy metals in plants and in soil is taken as an index of its capacity to bioaccumulate a metal from a contaminated soil (Yoon *et al*.,2006). If value of BCF is greater than 1 then the plants are classified as hyperaccumulators. BCF measures efficiency of a plant in accumulating a metal into its biomass. Results (Table.4) showed BCF>1 for Cr for all plant species at 1000 ppm concentrations except for *Sansevieria* with the value <1. For Zn and Ni none of the plant species were found to have BCF >1, but results for Zn and Ni were significant ($p<0.001$) compared to control with highest BCF value of 0.72 reported for Zn in *Nephrolepis* and least value of 0.35 was found for *Dracaena*. For Fe BCF value was found to >1 and significant as compared to controls for all test plant species and at both concentrations with the highest value of 2.44 for *Sansevieria* and least value of 1.19 for *Canna.* Lower values of BCF for Ni may be because of lower uptake of Ni by plants at lower concentrations.

Table 4. BCF of plants under different metal treatments (Values are presented as mean (±S.D); **represents significant differences between treatment and respective control at $p<0.001$, and * $p<0.05$)

| Metal concentration (ppm) | | Plant Species | | | | |
|---|---|---|---|---|---|---|
| | | *Tagetes erecta* | *Dracaena braunii* | *Nephrolepis exaltata* | *Canna indica* | *Sansevieria trifasciata* |
| Cr | Control | 1.56 ± 0.03 | 0.83 ± 0.02 | 1.60 ± 0.04 | 2.52± 0.05 | 2.64 ± 0.09 |
| | 500 | 1.23 ± 0.04** | 0.94 ± 0.03* | 1.35 ± 0.01* | 1.94± 0.07** | 0.72±0.03** |
| | 1000 | 1.19 ± 0.04** | 1.11 ± 0.05** | 1.02 ± 0.07** | 1.27± 0.04** | 0.72± 0.04** |
| Zn | Control | 0.37 ± 0.01 | 0.38±0.02 | 0.38 ± 0.00 | 0.46±0.01 | 0.48 ± 0.02 |
| | 500 | 0.49 ± 0.04* | 0.61±0.05** | 0.71 ± 0.02** | 0.51±0.02* | 0.47 ± 0.02 |
| | 1000 | 0.43 ± 0.03 | 0.35 ± 0.01 | 0.72 ± 0.07** | 0.38±0.02* | 0.31 ± 0.01* |
| Ni | Control | 0.13 ± 0.00 | 0.06±0.00 | 0.26 ± 0.00 | 0.32±0.01 | 0.26±0.02 |
| | 100 | 0.05 ± 0.00* | 0.02±0.00** | 0.09 ± 0.00** | 0.13±0.00** | 0.05±0.00** |
| | 300 | 0.13 ± 0.00 | 0.05±0.00** | 0.12 ± 0.00** | 0.15±0.00** | 0.09±0.00** |
| Fe | Control | 1.49 ± 0.05 | 0.85 ± 0.01 | 1.20 ± 0.03 | 1.1 ± 0.02 | 1.9 ± 0.05 |
| | 500 | 1.67 ± 0.25** | 1.92 ± 0.19** | 1.57 ± 0.1* | 1.19 ± 0.04* | 2.44± 0.07** |
| | 1000 | 1.82 ± 0.08** | 1.87 ± 0.03** | 1.64 ± 0.07** | 1.58± 0.04** | 1.94 ± 0.04 |

## 5. Conclusion

Metal accumulation in all test plant species was found to be dose dependent i.e. at higher concentration of metal uptake was higher. However, at higher concentration of metals tolerance index decline for test plant species resulting in visible signs of toxicity with maximum decline in Tolerance index noted for Cr. *T. erecta* was found to have least values for Tolerance index than other test plant species.

Among the tested plant species *T. erecta* shows considerable concentration of metals in its tissues, however it shows decline in biomass at higher concentration of metals with visible phytotoxicities. *T. erecta* though a good phytoremediator at lower concentrations of metals but prove to be highly sensitive plant at higher concentration of metals. *D. braunii* also could not tolerate high concentrations of metals resulted in visible signs of toxicities with no promising results as shown by Tolerance index and metal accumulation(mg/plant). *S. trifasciata* though accumulated lesser concentration of metals but its phytoremediation potential is compensated by producing high biomass. *N. exaltata* and *C. indica* extracted good amount of elements in their tissue and at the same time produce a good biomass as well as new growth indicated by their Tolerance index point towards their tolerance to these metals at higher concentrations. Based on this experiment *S. trifasciata*, *C. indica* and *N. exaltata* not only accumulate high metal concentration in their tissues but also show a great degree of tolerance thus can be explored further for their remediation capabilities at different concentrations of metals.

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