Effect of Cadmium-Contaminated Soil on the Growth of Different Ornamental Plants

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ABSTRACT

Background and Objective: Soil heavy metal contamination is a major issue caused by different natural factors including erosion, mineral weathering, volcano eruptions and anthropogenic factors such as mining, industrialization, urbanization and fertilizer use that affect plant growth and development. Therefore, the current study was designed to decline the levels of cadmium (Cd) in soil by growing different ornamental plants-*Matthiola incana*, *Antirrhinum majus* and *Gladiolus grandiflorus*.
Materials and Methods: To evaluate how *Matthiola incana*, *Antirrhinum majus* and *Gladiolus grandiflorus* respond to phytoremediation, seedlings were raised in pots according to a Completely Randomized Design (CRD) with a two-factor factorial arrangement. Different doses of Cd (0, 25, 50, 75 and 100 mg L^{-1}) were applied after one week of transplanting.
Results: The results revealed that Cd at lower concentrations (25 mg L^{-1}) moderately increased the growth parameters (shoot fresh and dry weights, root fresh and dry weights, shoot length and leaf area) compared to higher concentrations (100 mg L^{-1} Cd), showing reductions of 6.72, 19.06 and 21.55% for stock, snapdragon and gladiolus, respectively. Similarly, photosynthetic pigments (total chlorophyll) decreased with the increase of Cd by 6.49, 3.27 and 11.90% for stock, snapdragon and gladiolus at control, respectively. Gaseous exchange parameters (net photosynthesis rate, transpiration rate, stomatal conductance, substomatal conductance and water use efficiency) also decreased with the increase of Cd levels. Antioxidant enzyme activities (catalase, peroxidase and superoxide dismutase) showed similar responses, with changes of 2.4, 1.4 and 23.1% at 25 mg L^{-1} Cd concentration.
Conclusion: It was concluded that all three ornamental plants (*Matthiola incana*, *Antirrhinum majus* and *Gladiolus grandiflorus*) exhibited tolerance to lower Cd concentrations and could be effectively used for phytoremediation of Cd-contaminated soils, as higher Cd levels adversely affected plant growth and physiological attributes.

INTRODUCTION

Cadmium (Cd) is an important heavy metal which is harmful for plant life at low concentration as in comparison to different essential metals like Zn, Cu or Mn[1]. Micronutrients such as Zn, Fe, Ni and Mn[2] act as an activator of enzyme. They show their toxicity through inhibiting plant growth by disturbing the plant nutrient contents composition and numerous enzymes activities. Average Cd content inside the Earth's crust is expected to be 0.1 and 0.41 mg kg^{-1}. In plants Cd accumulation causes disturbance in physiological and morphological responses.

Heavy metal cadmium is regarded as a dangerous element because of its negative impact on both human health and the environment. Its atomic number in the periodic table is 48 and its chemical symbol is Cd. Urban wastewater containing municipal and industrial effluents is the main cause of soil Cd pollution in the majority of emerging nations. Vegetables are the primary crop grown on 32,500 hectares of agricultural land in Pakistan that is dependent on urban effluent[3]. Vegetable plants accumulate Cd from urban wastewater. According to Bisht et al[4]. soil nutrients are replaced by the harmful effects of Cd. Plants respond to Cd at a specific level, which stimulates enzyme activity but its high concentration fails the plant's defense system.

Therefore, in order to resolve the Cd contamination and toxicity issue, we must implement several management changes that will enable the plant to withstand metal stress. These approaches are expensive and have an impact on soil qualities through the addition of chelating agents, organic additives and growth regulators exogenously[5].

A simple and inexpensive solution to the above mentioned issue is phytoremediation. Plant-based bioremediation that accumulates, degrades, or sequesters contaminants from air, water, or soil is called phytoremediation. This process is economically and environmentally beneficial for plants[6].

The current study examines the potential of three ornamental plants (stock, snapdragon and gladiolus) for the remediation of copper-polluted soil. These plants are selected based on their robust and hardy nature as well as their ability to tolerate metal contamination.

MATERIALS AND METHODS

The current study was carried out in floriculture nursery, MNS University of Agriculture Multan during the year 2022-2023. There were two independent experiments. Each experiment was arranged according to Complete Randomized Design (CRD) with two factor factorial. Three ornamental plants (stock, snapdragon and gladiolus) were used in this study. Seedlings of stock and snapdragon were purchased from local nursery of Multan (Hammad nursery) while, corms of gladiolus were purchased from Khan Nursery Farm (Awagt Bangla Jaranwala Road Lahore). Gladiolus corms were soaked in Topsin M fungicide to avoid fungal effect on bulbs. Seedlings of stock (*Matthiola incana*) and snapdragon (*Antirrhinum majus*) and corms of gladiolus (Red Prosperity) were sown in 9 inches pot containing 4 kg soil per pot. Different dosses of Cd (0, 25, 50, 75 and 100 mg L^{-1}) was applied in the pot. On flowering stage all the three ornamental plants were harvested and separated carefully from the pots. For dry samples, soil was removed from the plants by gentle shaking and separates the shoot and root and placed into labeled paper bags and some samples placed into a plastic bags and stored into a refrigerator at -40°C for other parameters. Soil was collected and sent to soil and water testing laboratory for further analysis.

Seedlings of stock and snapdragon were transplanted and bulbs of gladiolus were placed into 9-inch pot and Cd (0, 25, 50, 75, 100 mg L^{-1}) was supplied to plants at selected levels. A completely randomized design (CRD) with two factor factorial arrangements having 5 treatments and 3 replications was used in this study.

The following parameters were studied in this study:

Growth parameter

Shoot fresh and dry weight (g): Plants (stock, snapdragon and gladiolus) shoot fresh and dry weight was recorded by digital balance while, dried weight were measured after placing the shoot in drying oven (POL-EKO-APARATURA SP.J.250 V) for 24 hrs at 62°C.

Root fresh and dry weight (g): Weight of the fresh and dry plant (stock, snapdragon and gladiolus) roots was recorded by digital balance while, dried weight were measured after placing the root in drying oven (POL-EKO-APARATURA SP.J.250 V) for 24 hrs at 62° C.

Shoot and root length (cm): Lengths of the plants stock, snapdragon and gladiolus parameters included root and shoot length were noted with the help of a centimeter scale.

Total chlorophyll: Using a KONICA MINOLTA SPAD 502 Chlorophyll Meter (Vi-21), the chlorophyll contents of the leaves of all 3 plants were measured.

Statistical analysis: A Complete Randomized Design (CRD) with two factor factorial arranged was used to conduct this experiment. Five treatments were used as independent variables each consisting of 3 replications. Data were Analyzed Using Analysis of Variance (ANOVA) followed by LSD tests for comparison among means by using software statistix version 8.1[7].

RESULTS

Shoot fresh weight (g): Shoot fresh weight of stock, snapdragon and gladiolus was significantly ($p<0.05$) affected by higher Cd application. Cd at its maximum level (100 mg L^{-1}) reduced the shoot fresh weight of all the three plants significantly. It also significantly reduced shoot fresh weight by 48.6, 55.4 and 67% in stock, snapdragon and gladiolus respectively at 100 mg L^{-1}, while application of Cd at the dose of 25 mg L^{-1} significantly reduced shoot fresh weight by 3, 19.8 and 15.6%, respectively compared with control (Fig. 1).

Root fresh weight (g): At maximum Cd concentration (100 mg L^{-1}), root fresh weight (g) was significantly reduced. In comparison to the control, the application of Cd at 100 mg L^{-1} led to a reduction in root fresh weight by 76.7, 50 and 81%, respectively for stock, snapdragon and gladiolus. Similarly, the application of Cd at the dose of 25 mg L^{-1} significantly reduced root fresh weight by 23.2

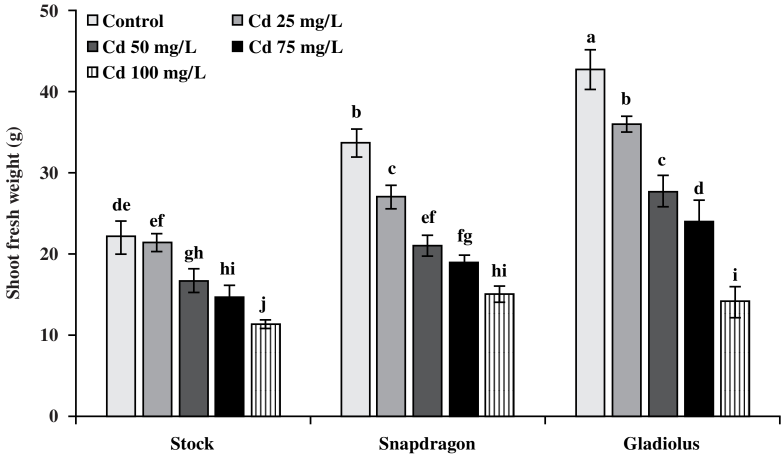

Fig.. 1: Shoot fresh weight (g) of three ornamental plant (stock, snapdragon and gladiolus) grown under different dosses of cadmium
The different alphabets show the significant difference between variety and treatments

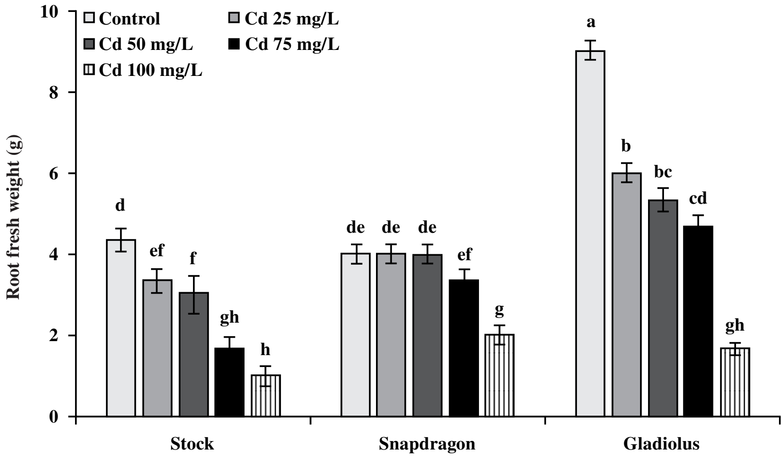

Fig. 2: Root fresh weight (g) of three ornamental plant (stock, snapdragon and gladiolus) grown under different dosses of cadmium
The different alphabets show the significant difference between variety and treatments

and 33.3% for stock and gladiolus and 17.5% for snapdragon at Cd 75 mg L^{-1}, respectively, as shown in Fig. 2.

Shoot dry weight (g): Cd at the maximum concentration (100 mg L^{-1}) significantly reduced the shoot dry weight of all three plants. Compared to the control, the application of Cd at 100 mg L^{-1} resulted in a reduction in shoot dry weight by 41%, followed by 78.3% at Cd 75 mg L^{-1} and 48.2% at Cd 50 mg L^{-1} for the respective plants. Similarly, the application of Cd at 25 mg L^{-1} led to a decrease in shoot dry weight by 8.33, 24.8 and 48.2% for stock, snapdragon and gladiolus, respectively, as depicted in Fig. 3.

Root dry weight (g): Statistical analysis of root dry weight (g) exhibited a significant difference ($p<0.05$) among all three ornamental plant species across all levels of Cd (0, 25, 50, 75 and 100 mg L^{-1}). The drastic decline was observed at of higher concentrations of Cd. At maximum Cd level (100 mg L^{-1}), the root dry weight of all three plants was reduced compared to the control condition. The application of Cd at 100 mg L^{-1}resulted in a reduction in root dry weight by 36, 61.53 and 69.1% for stock, snapdragon and gladiolus, respectively. Similarly, in comparison to the control, the application of Cd at 25 mg L^{-1} decreased the root dry weight by 14.7, 30.76 and 52.8% for stock, snapdragon and gladiolus, respectively, as depicted in Fig. 4.

Shoot length (cm): The application of Cd (0, 25, 50, 75 and 100 mg L^{-1}) changed the shoot length of stock, snapdragon and gladiolus (Fig. 5). The control plants, exhibited the highest shoot length compared to all other levels. In comparison to the control, a minimum reduction (6.72, 19.06 and 21.55%) was observed in stock, snapdragon and gladiolus, respectively, at 25 mg L^{-1}Cd. However, higher

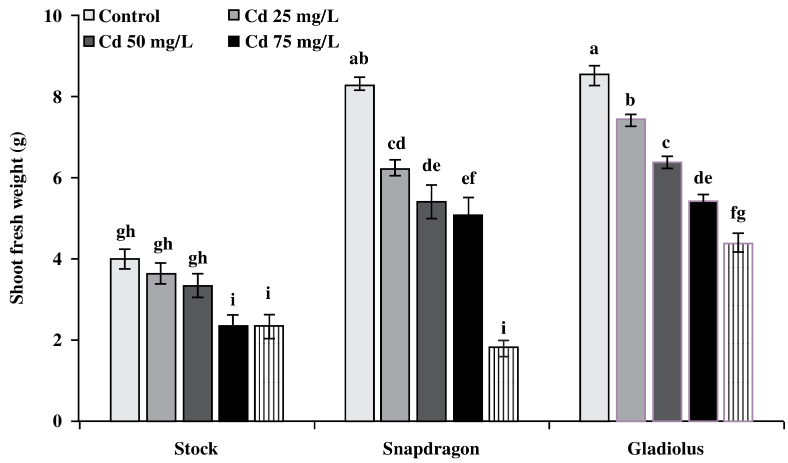

Fig. 3: Shoot dry weight (g) of three ornamental plant (stock, snapdragon and gladiolus) grown under different dosses of cadmium
The different alphabets show the significant difference between variety and treatments

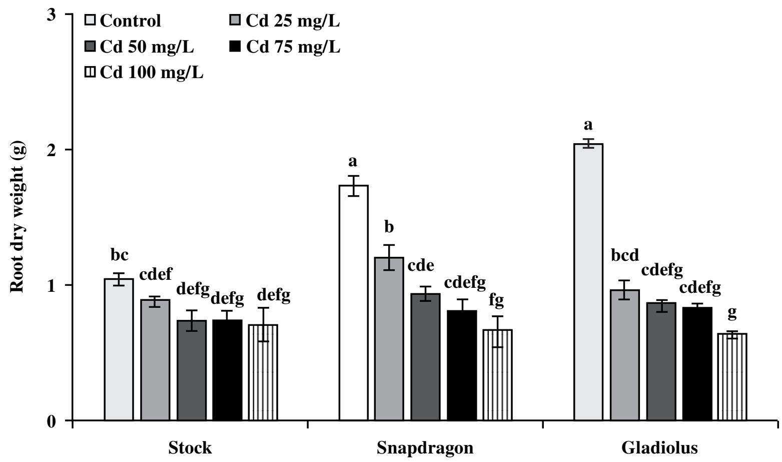

Fig. 4: Root dry weight (g) of three ornamental plant (stock, snapdragon and gladiolus) grown under different dosses of cadmium
The different alphabets show the significant difference between variety and treatments

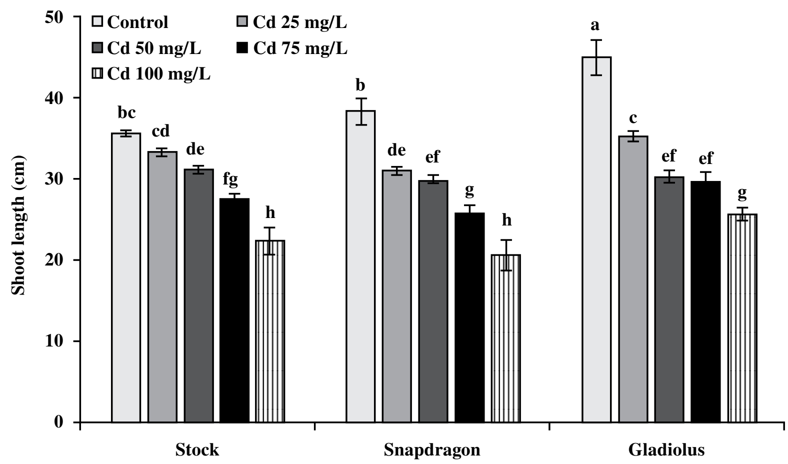

Fig. 5: Shoot length (cm) of three ornamental plant (stock, snapdragon and gladiolus) grown under different dosses of cadmium
The different alphabets show the significant difference between variety and treatments

Cd application at 100 mg L^{-1} had a detrimental impact on the plants. The shoot length of stock, snapdragon and gladiolus decreased by 37.53, 45.3 and 42.8%, respectively, at 100 mg L^{-1} Cd with respect to control.

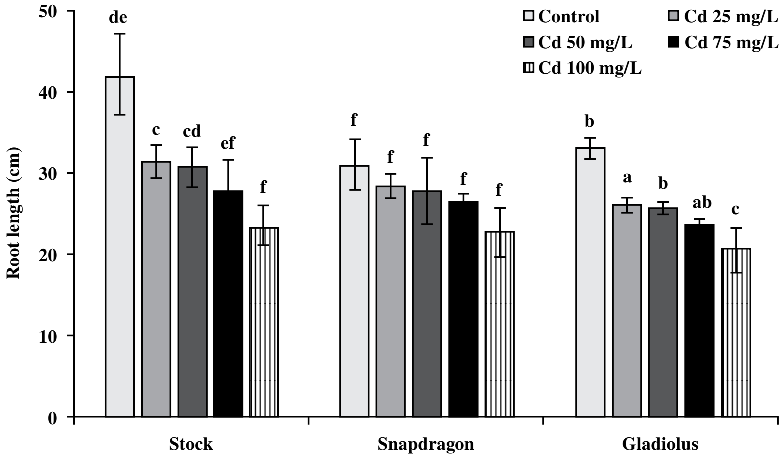

Fig. 6: Root length (cm) of three ornamental plant (stock, snapdragon and gladiolus) grown under different dosses of cadmium
The different alphabets show the significant difference between variety and treatments

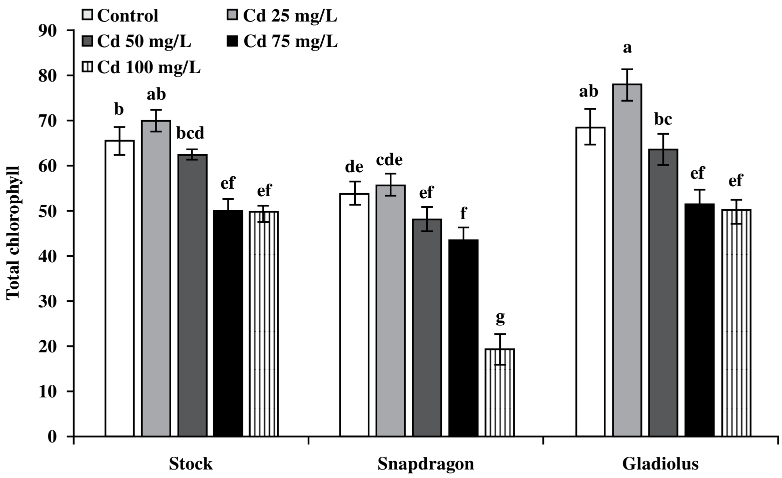

Fig. 7: Total chlorophyll of three ornamental plant (stock, snapdragon and gladiolus) grown under different dosses of cadmium
The different alphabets show the significant difference between variety and treatments

Root length (cm): The root length data of three ornamental plants stock, snapdragon and gladiolus at various levels of Cd (0, 25, 50, 75 and 100 mg L^{-1}) showed non-significant interaction V*T ($p<0.05$) (Fig. 6). Compared to other treatments, all the three plants had higher root length under control. Minimum root length of stock, snapdragon and gladiolus was decreased by 25.3, 8.61 and 21.2% respectively at Cd 25 mg L^{-1} with relative to control and maximum root length of stock, snapdragon and gladiolus decreased by 44.4, 26.9 and 37.3%, respectively for Cd 100 mg L^{-1} with comparison to control. From all the three plants maximum root length (44.4%) was observed in stock and then in gladiolus (37.3%).

Total chlorophyll: Significant differences ($p<0.05$) were observed for total chlorophyll among the three ornamental plants across all levels of Cd (0, 25, 50, 75 and 100 mg L^{-1}). Maximum Cd concentration (100 mg L^{-1}), was reduced. In comparison to the Cd 25 mg L^{-1}, the application of Cd at 100 mg L^{-1} led to a reduction in total chlorophyll by 28.8, 65.47 and 35.66%, respectively for stock, snapdragon and gladiolus. Similarly, the application of Cd at 25 mg L^{-1} resulted in a minimum decrease in total chlorophyll by 6.49, 3.27 and 11.90% for stock snapdragon and gladiolus respectively, as shown in Fig. 7.

DISCUSSION

Results of the present study showed that higher Cd levels reduced the plant growth of stock, snapdragon and in gladiolus. In comparison to the control, a minimum shoot length reduction (6.72, 19.06 and 21.55%) was recorded in stock snapdragon and in gladiolus respectively. Whereas, compared to the control, the shoot length of stock, snapdragon and gladiolus decreased significantly by 37.53, 45.3 and 42.8%, respectively, at 100 mg L^{-1} Cd (Fig. 5). Decreased growth of ornamental plants (stock, snapdragon and gladiolus) in Cd polluted soil may be due to decreased relative water content and photosynthetic pigment that effected the photosynthetic activity. Similar results were reported by Bukhari et al[8]. who observed decrease in aerial parts of gladiolus plant with increase in Cd level.

A gradual reduction in plant length in the presence of Cd was recorded in ornamental plants. Similar findings for plant height were reported by Mani et al.[9], who found that elevated Cd levels in gladiolus reduce plant height. Similar findings were reported by Shah et al.[10] who evaluated the effect of Cd on the growth characteristics of *Tagetes erecta* plant. In agreement with the current results, Lal et al.[11] observed reduction in dry shoot weight in higher Cd polluted soil when he evaluated the effect of Cd on chrysanthemum, gladiolus and marigolds.

The reduced shoot length and dry-mass production in the presence of higher amount of Cd exposure, along with stunted growth that reduced the exposed area to sunlight with inadequate photosynthetic performance, may have caused the perturbed rate of gas exchange parameters. Internal Cd toxicity also interfered with plant physiological function. Reduced physiological and gas exchange activity, resulted in decreased physical performance.

In present study, the increase was observed in chlorophyll content of stock, snapdragon and gladiolus respectively at 25 mg L^{-1} as compared to control. Similarly Liu et al.[12] also reported that, the increase in chlorophyll content of *L. japonica* at 5 mg L^{-1} Cd suggests that this concentration may be beneficial to plant growth. This is consistent with the findings of Kinraide[13] who reported that aluminum can enhance plant growth by increasing iron solubility, promoting phosphorus uptake and protecting against copper and manganese toxicity.

Significant reduction was observed in membrane stability index (MSI) with the increase in Cd level. The process of Reactive Oxygen (RO) attacking Phospholipid Molecules Containing Polyunsaturated Fatty Acids (PUFA) in cell membranes is widely recognized. This attack leads to the production of a toxic byproduct called MDA, which is responsible for damaging the cell membrane[6]. These findings align well with the conclusions of several other researchers who have demonstrated that heavy metal exposure significantly reduced the Membrane Stability Index (MSI)[14].

Our findings demonstrated that Cd based stress induction decreases the characteristics of gas exchange. This reduction might be due to destruction of photosynthetic pigments in response to higher ROS production and reduced antioxidative enzyme production. These findings are fully corroborated with Chen et al.[15], who stated that Cd stress adversely affected the photosynthetic rate of plant like lettuce, pennisetum etc. Similar results were reported by Shah et al.[16], who found that Cd stress effects plant growth by disturbing the photosynthetic activity in *Brassica oleracea*.

In the curent study, the SOD level increase at higher level of Cd (100 mg L^{-1}) in snapdragon as compared to Cd 75 mg L^{-1}. The SOD has been described as the most significant antioxidant enzyme[17]. A similar increase in SOD activity was observed in plant species (*Alternanthera bettzickiana*, *Coronopus didymus* and *papolus*) exposed to Cd stress[18]. According to Li et al.[19], high levels of lipid peroxidation were observed in *Moso bamboo* under cadmium stress, suggesting oxidative stress in cellular structures. Likewise, Hameed et al.[20], reported the progressive increase in MDA content with higher cadmium concentrations in strawberry, suggesting a correlation between lipid peroxidation and exposure to heavy metal pollution.

CONCLUSION

Cd toxicity in soil adversely affected the growth and development of snapdragons and gladiolus in the present study. At lower doses of Cd (25 mg L^{-1}), ornamental plants absorb heavy metals from soil with minimal impact on growth.

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