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EFFECT OF CADMIUM TOXICITY ON Zn, Mn, Cd, Fe CONCENTRATION AND TRANSLOCATION, BIOACCUMULATION, UPTAKE OF Cd IN ROOT AND SHOOT OF DIFFERENT RICE VARIETIES

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Abstract

Rice (*Oryza sativa* L.) is found a paramount contributor (>75%) of Cd contamination in the food chain in many countries of Asia, including Pakistan. In the present study, twenty local rice varieties were selected and the varietal response was investigated against Cd application with four strengths (0, 5, 10, and 15 µM) under hydroponic conditions by following completely randomized design under the factorial arrangements along with three replicates. Results regarding Cd concentration in roots and shoots revealed that the maximum level of Cd was assessed in V_{20} (IRRI-6) and minimum in V_1 (Super Basmati) when Cd was applied at a higher level (15 µM), while higher Cd uptake in roots and shoots was exhibited by V_{20} (IRRI-6) and V_{13} (KS-282) respectively and minimum in V_1 (Super Basmati) among both ones at Cd application with strength 15 µM. Maximum translocation and bioaccumulation of Cd in roots and shoots were observed in V_{20} (IRRI-6) and minimum in V_1 (Super Basmati). Zinc level in root was higher in V4 (Shaheen Basmati) and minimum in V_{14} (KSK-133), while, in shoots V_7 (Basmati-515) exhibited maximum Zn concentration and minimum by V_2 (Kainat Basmati). Maximum Mn level in roots against Cd application were observed in V_4 (Shaheen Basmati) and minimum in V_2 (Kainat Basmati), whereas its level was higher in shoots of V_{13} (KS-282) and lower in V_8 (Pak Basmati). Iron contents were higher in roots of V_5 (Basmati-198) and lower in V_{20} (IRRI-6), while, in shoots, Fe level was higher in shoots of V_8 (Pak Basmati) and minimum in V_2 (Kainat Basmati) against Cd application. V_1 (Super Basmati) showed a positive response against Cd contaminations. This study enlightens the era for others to assess the impact of heavy metals on various crops. Increasing the Cd concentration higher the binding to sulfhydryl groups in proteins and enzymes that inactive and disturb the metabolic pathway of rice plant and decrease uptake of essential nutrients. Cd competes with the nutrients and damages the plant nutrients balance and create physiological stress.

Key words: Cadmium, Food pollution, Heavy metals, Hydroponics, Rice varieties, Screening.

Introduction

Producing more food for the swelling population is an enormous challenge throughout the world. Food security in developing countries hinges on local production and needs ingenious concerns to fulfill the every malnutrition, efficient use of genetic resources, and biodiversity (Garrity *et al*., 2010; Zaheer *et al*., 2019). Wheat and Rice are two key bowls cereals to meet food requirements globally. Rice (26% of total cereals production) contributes to food for nearly half the population in the world and is considered the second most consumed food by humans (Yanjie *et al*., 2018). Only in Asia, it is the food source of more than 2 billion population. Widely, it is cultivated in Pakistan, India, Thailand, China, Bangladesh, Vietnam, Myanmar, Indonesia, and Japan. 92% of world production is coming from Asian countries. It is 3rd most abundant sown crop (16% of total cereals) after wheat and cotton in Pakistan contributing 3% in value-added products and 0.6% to GDP (Asghar *et al*., 2014). Production of rice during 2018-19 was 3.3% less than the previous year (7.4 million tons) due to water shortage, dry weather, and less domestic price for the farmers (Anon., 2019). Rice grain contains nearly 80 to 85% starch, protein about 4 to 10%, 1% lipid, and approximately 10% moisture hence plays a vital role in meeting daily food needs (Balindong *et al*., 2018).

The use of synthetic fertilizers, and untreated industrial and sewage water are sources of heavy metals in crop plants cause of increasing toxicity in food chain (Liu *et al*., 2018). Heavy metals impart negative possessions on the biochemical and physiological functions of plants (Zaheer *et al*., 2022). These negative impacts include leaf rolling, efflux of cations, altered stomatal functions, decreased water potential, change in enzyme activities, necrosis damage to the respiration process, and photosynthesis (Lu *et al*., 2022). Among all heavy metals, Cd plays a major role in contaminating water and soil. Its small quantity causes health hazards for the user (Yu *et al*., 2006). The concentration of Cd in water can range from 0.023 mg/L to 1.481 mg/L while in soil permissible limit is

100 mg kg^{-1}. Cd is readily absorbable into the soil and becomes part of many crop plants after mixing in water. Different crop families have a different range of Cd concentrations in them. For example, for cereal grains is about 0.013 to 0.22 mg/kg, for grasses it may range from 0.07 to 0.27 mg/kg and for legume shoots it is about 0.08 to 0.28 mg/kg (Kabata-Pendias & Henryk, 2000).

Rice is found a major contributor (>75%) of Cd contamination in the food chain in many countries of Asia and the most damaged crop (Farooqi *et al.*, 2009). Cd accelerates the production of free metal radicals in rice plants which reduces seed germination, root length, shoot length, number of leaves and causes necrosis (Pal *et al.*, 2007). It causes insufficient production of chlorophyll and cell lysis that ultimately leads to plant death due to alteration in enzyme functions, respiration, and photosynthesis (Qin *et al.*, 2022). Elevated levels of Cd might cause growth reduction of crops through the carbon fixation mechanism because of lower chlorophyll concentration and rate of photosynthesis. Therefore, it is suggested that the concentration of Cd must be monitored in plant cells so that it remains within the safe limit (Cohen *et al.*, 1998). Efforts are conducted either to prevent or at least reduce the chances of uptake of Cd in rice crops. Eco-physiological mechanisms depend on the physical properties of soil and the morphological properties of the plant (Yuan *et al.*, 2023). Physical properties that affect Cd uptake are soil redox potential, pH, trace element extent, and organic matter in the soil. Like other metals such as calcium, iron, and zinc, Cd is normally taken up via a metabolic pathway (Zhang *et al.*, 2021). During the past few years, many carriers for Cd in rice plants have been discovered. The NRAMPs (Natural Resistance Associated Macrophage Proteins) formulate a massive group that is conserved evolutionary through the organisms. These Nramps are associated with the intercellular shifting, detoxification, uptake, and translocation of transition metalloids. There are seven Nramp. Genes present in the rice genome, out of which two have been functionally categorized at the molecular and cellular levels. OsNramp5 is identified to mediate Cd transport (Pal *et al.*, 2007).

The concentration and toxicity of Cd not only depend upon plant species but also on cultivars. In many crop species, the distribution of Cd within different plant parts such as shoots, and roots also vary within different species of rice. Effects of cadmium on rice plant solution culture research was carried out to evaluate the uptake of Cd within locally cultivated various genotypes of rice. The objective of the study was to find out the more tolerant genotype for local farmers and eventually make food chain safe.

Material and Methods

Twenty rice varieties {Super Basmati (V_1), Kainat Basmati (V_2), Super Kernel Basmati (V_3), Shaheen Basmati (V_4), Basmati-198 (V_5), Basmati-2000 (V_6), Basmati-515 (V_7), Pak Basmati (V_8), Basmati-385 (V_9), Basmati-370 (V_{10}), 99417 (V_{11}), 99404 (V_{12}), KS-282 (V_{13}), KSK-133 (V_{14}), KSK-434 (V_{15}), PS-2 (V_{16}), IR-6 (V_{17}), SRI-13 (V_{18}), IRRI-9 (V_{19}), IRRI-6 (V_{20})} commonly grown in Punjab (Pakistan) were selected for solution culture experiment at UAF (University of Agriculture Faisalabad) Pakistan. These varieties were collected from Rice Research Institute Kala Shah Kako Lahore and Ayub Agriculture Research Institute Faisalabad, Pakistan.

The sand was used to raise the nursery in wire house, trays having 2 inches of the sand layer were used to raise the nursery using uniform and healthy seeds of selected varieties on 03/05/2018. Before rising the nursery culture medium (sand) was washed initially four times with tap water to remove dust particles, three times with distilled water, three times with 0.01 N HCL solutions, and four times with distilled water. The raised nursery was irrigated with distilled water. Fifteen days old nursery of all varieties was shifted to tubes (200 L capacity) containing four lines of holes in thermopore sheet of 1inch thickness. One hole contained only one plant supported by foam in the hole. The roots of plants were dipped in Johnson's solution of half strength and aeration was applied using an aquarium pump (Johnson *et al.*, 1957). Fertilizers were applied in dissolved form as per recommendations of the agriculture department, Punjab (120-80-60 NPK/ha), as per the requirement of our experimental area.

After 7 days of transplantation four concentrations of Cd were marinated via $CdCl_2.H_2O$ salt (Zhang *et al.*, 2014). Treatment concentrations were T_1 (Cd 0 µM L^{-1}), T_2 (Cd 5 µM L^{-1}), T_3 (Cd 10 µM L^{-1}) and T_4 (Cd 15 µM L^{-1}). Three replications of each treatment were taken for collection of data. The pH of nutrient solution was controlled to 6.0 ± 0.5 by using 0.5 N NaOH/HCl. Plant samples were washed away with acidified water tracked by distilled water.

After 15 days of Cd application, plant samples were divided into root and shoot and were examined using metal analysis. Half gram plant samples were dried in conical flask after treatment of HNO_3 and $HCLO_4$ at 2:1 using standard procedure described by Zhang *et al.*, (2014). These plant samples were digested using hot plate method and 25ml volume of sample was made using distilled water after cooling of digested plants. Prepared volume was then passed through filter paper (No. 42) and was used for analysis by mean of Atomic Absorption Spectrometer.

Root and shoot Cd uptake was calculated by following formulae (Wang *et al.*, 2005).

Root/Shoot Cd Uptake (g/kg) = {Root / shoot dry weight (g) x Root /shoot Cd Con. (mg/kg)} / {1000}

Cd Bioaccumulation factor (BCF) was determined as using the following formula;

Cd Bioaccumulation in Roots = Cd Concentration in Roots (g kg^{-1}) /Cd Con. in growth medium (mg/L)

Translocation of Cd of root to shoot was determined by the formula as described by Xiao *et al.*, (2021).

Translocation Factor = Cd Con. in Shoots (mg/kg) / Cd Con. in Roots (mg/lg).

Data obtained for plant growth and chemical parameter were subject for analysis of variance by using the Statistix (8.1) software. Means were compared subsequently by LSD at 5% probability level (Steel *et al.*, 1997).

Results

Results in revealed that various rice varieties and Cd levels showed significant variation ($p \leq 0.01$) for Cd concentration in root and shoot samples. Both the factors exhibited statistically significant results, while the interactive effect of both factors also showed significant results for the Cd concentration in root and shoots samples. Maximum Cd concentration in roots and shoots (92.03, 13.86 mg kg^{-1}) respectively in V_{20} was observed where the seedlings of rice varieties were dipped in the solution of Cd having the strength (15 µM) followed by (10 µM), while minimum Cd concentration in roots and shoots (3.3, 0.18 mg kg^{-1}) respectively in V_1 was noticed in where the rice seedling were dipped in only nutrient solution (control). The decreasing pattern in Cd concentration in roots and shoots for Cd levels was $T_4 > T_3 > T_2 > T_1$ while for rice varieties was $V_{20} > V_{13} > V_{19} > V_{16} > V_{15} > V_6 > V_{10} > V_5 > V_7 > V_8 > V_{14} > V_{11} > V_{17} > V_{18} > V_{12} > V_9 > V_3 > V_2 > V_4 > V_1$ (Fig. 1), whereas, decreasing trend for shoot was $V_{20} > V_{13} > V_{19} > V_{16} > V_{15} > V_6 > V_7 > V_5 > V_{10} > V_8 > V_{14} > V_{11} > V_{17} > V_{18} > V_9 > V_3 > V_{12} > V_4 > V_2 > V_1$ (Fig. 2).

Results revealed that various rice varieties and Cd levels showed significant variation ($p \leq 0.01$) for Cd uptake in root and shoot samples. Both the factors exhibited statistically significant results, while the interactive effect of both factors also showed significant results for the Cd uptake in root and shoot samples. Maximum Cd uptake in roots and shoot (0.266 g kg^{-1}, 0.038 g kg^{-1}) respectively in V_{13} was observed where the seedlings of rice varieties were dipped in the solution of Cd having the strength (15 µM) followed by (10 µM), while minimum Cd uptake in roots and shoots (0.003, 0.001 g kg^{-1}) respectively in V_1 was noticed in where the rice seedling were dipped in only nutrient solution (control). Overall decreasing pattern in Cd uptake in roots and shoots for Cd levels was $T_4 > T_3 > T_2 > T_1$ while for rice varieties was $V_{20} > V_{13} > V_{19} > V_5 > V_{16} > V_{15} > V_{14} > V_{18} > V_{12} > V_{11} > V_9 > V_6 > V_{10} > V_7 > V_3 > V_8 > V_2 > V_{17} > V_4 > V_1$ (Fig. 3)., whereas, decreasing trend for shoot Cd uptake was $V_{13} > V_{20} > V_{15} > V_{16} > V_{19} > V_5 > V_7 > V_6 > V_{10} > V_{11} > V_{14} > V_{18} > V_8 > V_{17} > V_4 > V_3 > V_9 > V_2 > V_{12} > V_1$ (Fig. 4).

Results revealed that various rice varieties and Cd levels showed significant variation ($p \leq 0.01$) for Cd translocation from root to shoot. Both the factors exhibited statistically significant results, while the interactive effect of both factors also showed significant results for the Cd translocation. Maximum Cd translocation from roots to shoots (0.151% in V_{20}) was observed where the seedlings of rice varieties were dipped in the solution of Cd having the strength (15 µM) followed by (10 µM), while minimum Cd translocation from roots to shoots (0.19% in V_9) was noticed in where the rice seedling were dipped in only nutrient solution (control). Overall decreasing pattern in Cd translocation in roots to shoots for Cd levels was $T_1 > T_4 > T_2 > T_3$ while for rice varieties was $V_{20} > V_{13} > V_{19} > V_{16} > V_{15} > V_{14} > V_{11} > V_8 > V_{10} > V_6 > V_5 > V_{17} > V_7 > V_{18} > V_9 > V_3 > V_{12} > V_4 > V_2 > V_1$ (Fig. 5). Growth of plant was normal, in control treatment, suggesting that higher transpiration and photosynthetic rate assisted increased Cd translocation to shoots.

Results revealed that various rice varieties and Cd levels showed significant variation ($p \leq 0.01$) for Cd bioaccumulation in root and shoot samples. Both the factors exhibited statistically significant results, while the interactive effect of both factors also showed significant results for the Cd bioaccumulation in root and shoot samples. Maximum Cd bioaccumulation in roots (0.204 in V_{20}) was observed where the seedlings of rice varieties were dipped in the solution of Cd having the strength (5 µM) followed by (10 and 15 µM), while minimum Cd bioaccumulation in roots (0.106 in V_1) was noticed in where the rice seedling were dipped in solution having strength (15 µM). Maximum Cd bioaccumulation in shoot (0.023 in V_{16}) was observed where the seedlings of rice varieties were dipped in the solution of Cd having the strength (15 µM) followed by (10 µM), while minimum Cd bioaccumulation in shoots (0.003 in V_{12}) was noticed in where the rice seedling were dipped in solution having strength (5 µM). Overall decreasing pattern in Cd bioaccumulation in roots and shoots for Cd bioaccumulation levels was $T_2 > T_3 > T_4 > T_1$ while for rice varieties was $V_{20} > V_{13} > V_{19} > V_{16} > V_{15} > V_6 > V_{10} > V_5 > V_7 > V_8 > V_{14} > V_{11} > V_{17} > V_{18} > V_{12} > V_9 > V_3 > V_2 > V_4 > V_1$ (Fig. 6)., whereas, decreasing trend for shoot Cd bioaccumulation was $V_{20} > V_{26} > V_{13} > V_{19} > V_6 > V_{10} > V_7 > V_{15} > V_8 > V_{17} > V_{11} > V_5 > V1_8 > V_9 > V_{14} > V_{12} > V_2 > V_3 > V_4 > V_1$ (Fig. 7)..

Results revealed that various rice varieties and Cd levels showed significant variation ($p \leq 0.01$) for Zn concentration in root and shoot samples. Both the factors exhibited statistically significant results, while the interactive effect of both factors also showed non-significant results for the Zn concentration in root, whereas significant results exhibited in case of shoot samples. Maximum Zn level in roots and shoot (76.66 mg kg^{-1} in V_4) was observed where the seedlings of rice varieties were dipped in the solution of Cd having the strength (5 µM) followed by (10 µM), Lowest Zn con. in roots (9.68 mg kg^{-1} in V_8) were noticed in where the rice seedling were dipped in solution having strength (15 µM). Minimum Zn level in shoot (4.82 mg kg^{-1} in V_{10}) was observed where the seedlings of rice varieties were dipped in the solution of Cd having the strength (10 µM) followed by (15 µM), while maximum Zn concentration in shoots (26.65 mg kg^{-1} in V_7) was noticed in where the rice seedling were dipped in only nutrient solution (control). Overall decreasing pattern in Zn concentration in roots and shoots for Cd levels was $T_1 > T_2 > T_3 > T_4$ and $T_1 > T_2 > T_4 > T_3$ respectively while for rice varieties was $V_4 > V_{12} > V_{11} > V_{17} > V_6 > V_3 > V_2 > V_7 > V_{15} > V_8 > V_9 > V_{13} > V_{16} > V_{20} > V_{10} > V_{19} > V_{18} > V_1 > V_5 > V_{14}$ (Fig. 8), whereas, decreasing trend for shoot Zn level was $V_7 > V_9 > V_{17} > V_3 > V_{12} > V_{18} > V_{19} > V_{15} > V_{14} > V_{13} > V_1 > V_{20} > V_{10} > V_4 > V_8 > V_{16} > V_5 > V_{11} > V_6 > V_2$ (Fig. 9).

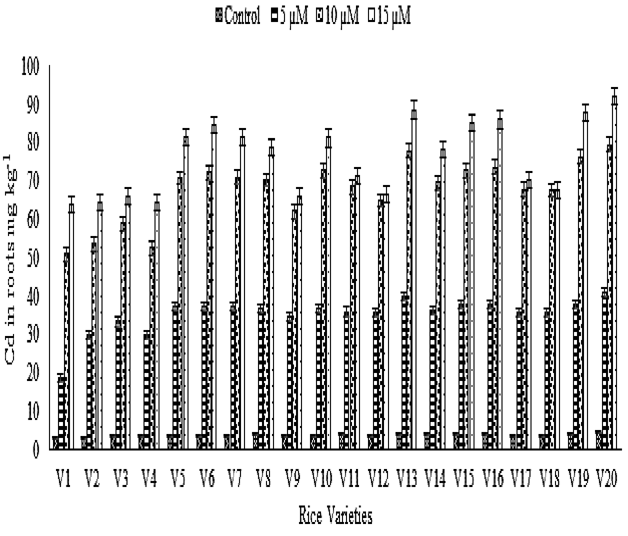

Fig. 1. Root Cd concentration (mg kg^{-1}) in rice as affected by application rates of Cd.

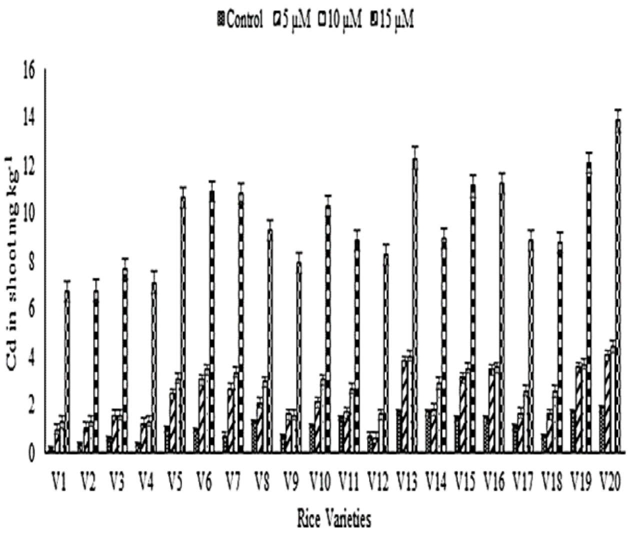

Fig. 2. Shoot Cd concentration (mg kg^{-1}) in rice as affected by application rates of Cd.

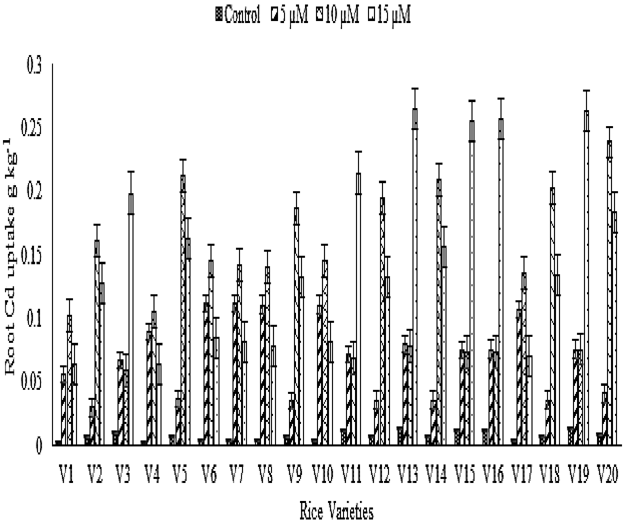

Fig. 3. Effect of Cd on Cd uptake of root (g/kg) in different rice varieties.

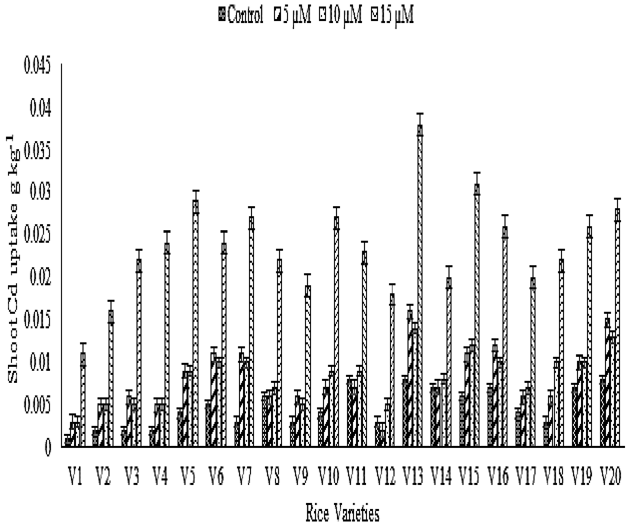

Fig. 4. Effect of Cd on Cd uptake of shoot (g/kg) in different rice varieties.

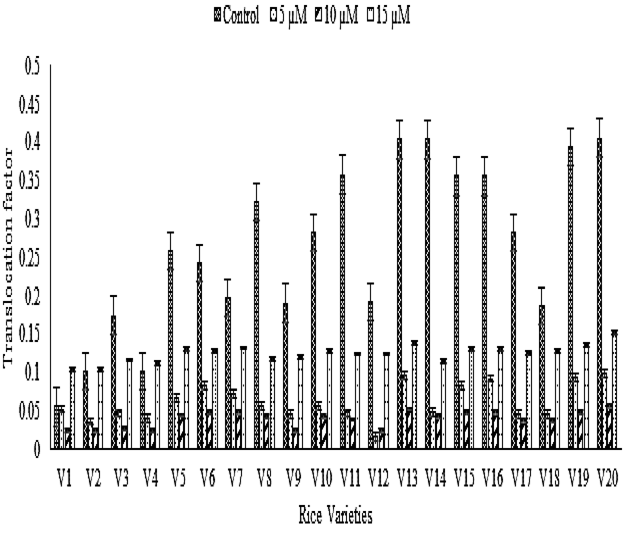

Fig. 5. Translocation factor of Cd in rice as affected by application rates of Cd.

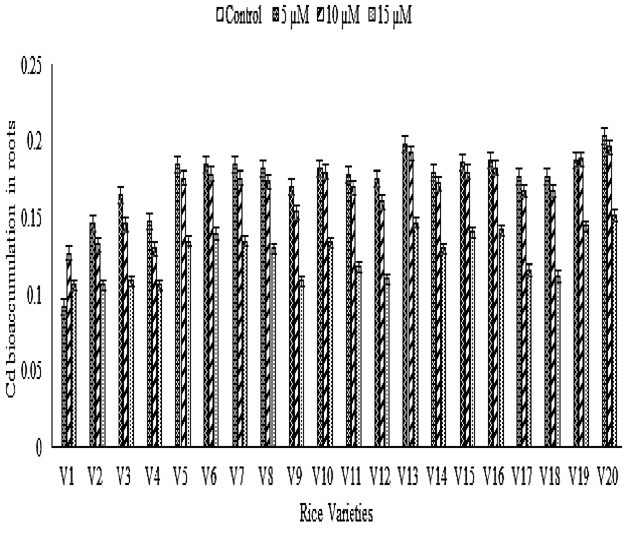

Fig. 6. Effect of Cd on Bioaccumulation factor of Cd in different rice varieties.

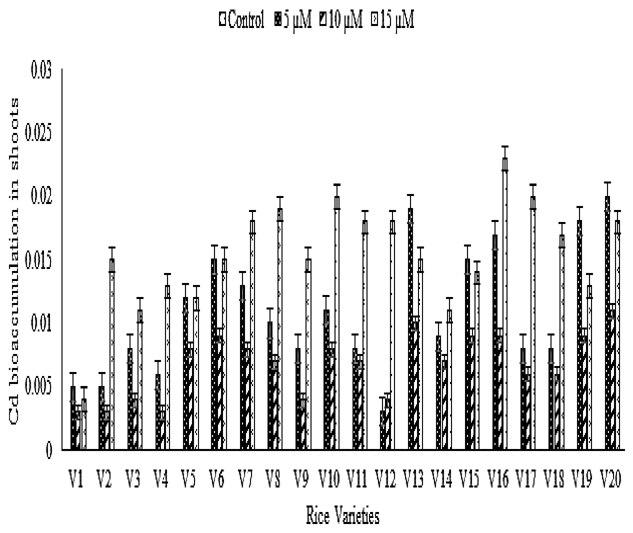

Fig. 7. Bioaccumulation factor of Cd in rice shoots as affected by application rates of Cd.

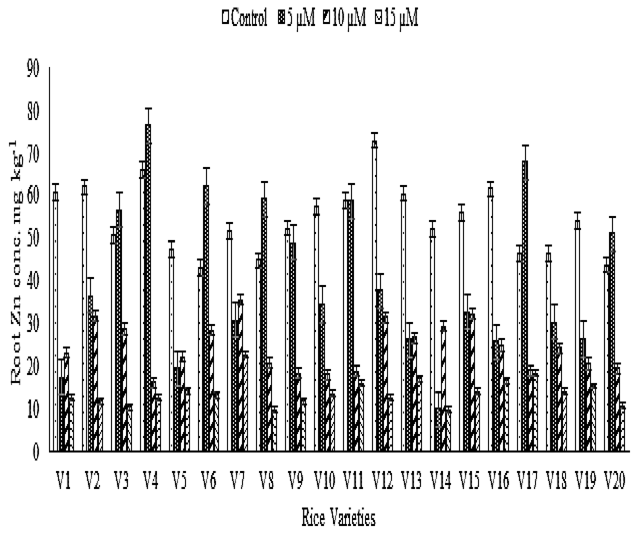

Fig. 8. Root Zn concentration (mg kg^{-1}) in rice as affected by application rates of Cd.

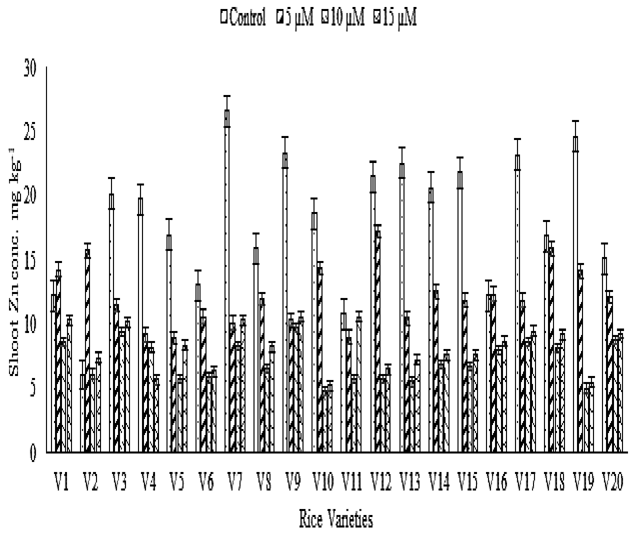

Fig. 9. Shoot Zn concentration (mg kg^{-1}) in rice as affected by application rates of Cd.

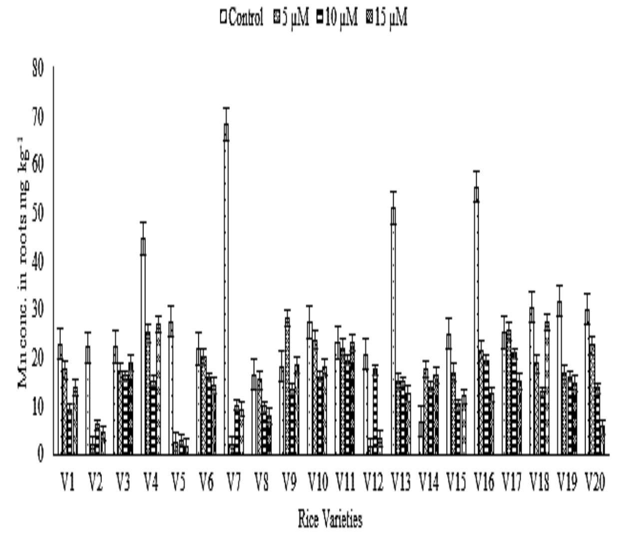

Fig. 10. Root Mn concentration (mg kg^{-1}) in rice as affected by application rates of Cd.

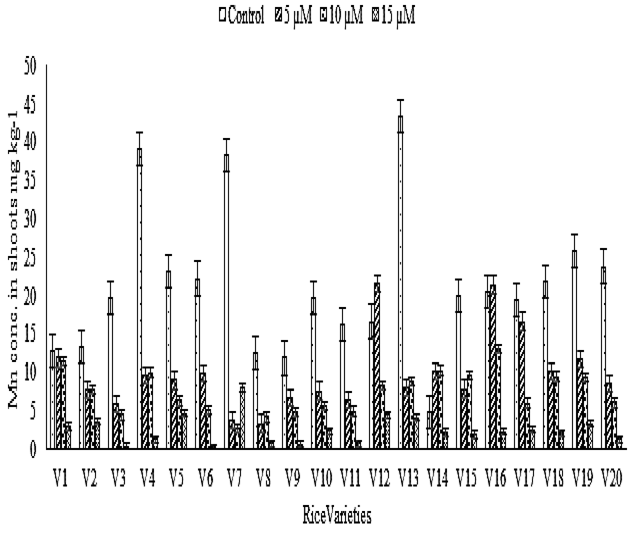

Fig. 11. Shoot Mn concentration (mg kg^{-1}) in rice as affected by application rates of Cd.

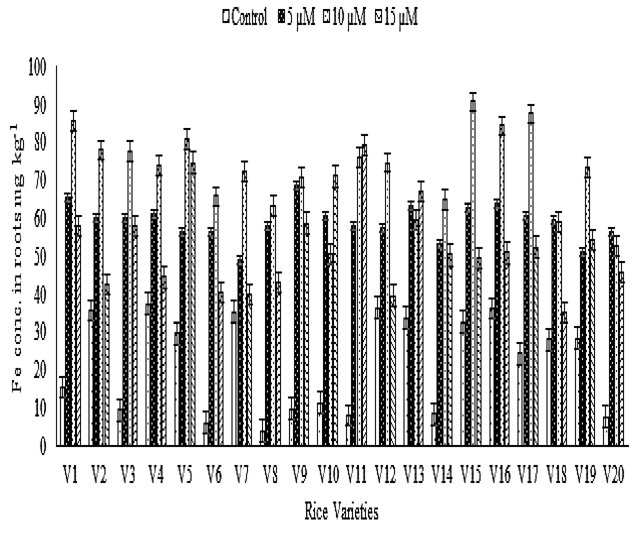

Fig. 12. Root Fe concentration (mg kg^{-1}) in rice as affected by application rates of Cd.

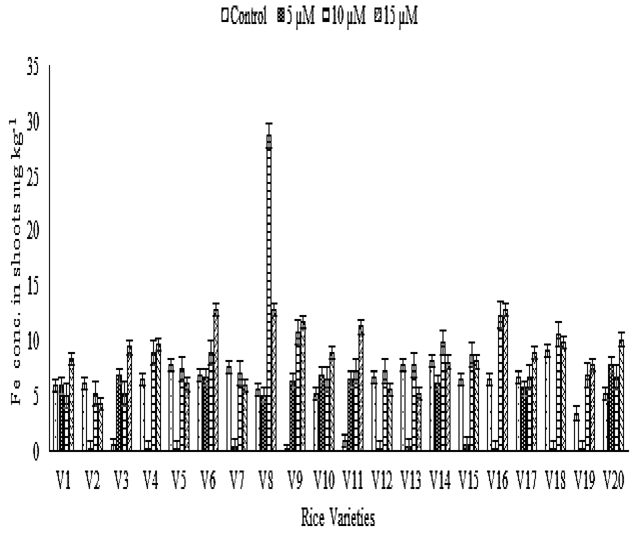

Fig. 13. Effect of Cd on Shoot Fe concentration (mg/kg) in different rice varieties.

Results revealed that various rice varieties and Cd levels showed significant variation (*p*≤0.01) for Mn concentration in root and shoot samples. Both the factors exhibited statistically significant results, while the interactive effect of both factors also showed significant results for the Mn concentration in root and shoots samples. Minimum Mn concentration in roots and shoots (1.39 mg kg^{-1} in V_{12}) was observed where the seedlings of rice varieties were dipped in the solution of Cd having the strength (5 µM) followed by (15 µM), while maximum Mn concentration in roots and shoots (68.31 mg kg^{-1} in V_7) was noticed in where the rice seedling were dipped in only nutrient solution (control). Minimum Mn concentration in shoots (0.17 mg kg^{-1} in V_6) was observed where the seedlings of rice varieties were dipped in the solution of Cd having the strength (15 µM) followed by (10 µM), while maximum Mn concentration in roots and shoots (43.53 mg kg^{-1} in V_{13}) was noticed in where the rice seedling were dipped in only nutrient solution (control). The decreasing pattern in Mn concentration in roots for Cd levels was $T_1 > T_2 > T_3 > T_4$ while for rice varieties was $V_4 > V_{16} > V_{13} > V_7 > V_{18} > V_{11} > V_{17} > V_{10} > V_{19} > V_9 > V_3 > V_6 > V_{20} > V_{15} > V_1 > V_{14} > V_8 > V1_2 > V_5 > V_2$ (Fig. 10), whereas, decreasing trend for shoot was $V_{13} > V_4 > V_{16} > V_7 > V_{12} > V_{19} > V_{17} > V_{18} > V_5 > V_{20} > V_{15} > V_1 > V_6 > V_{10} > V_2 > V_3 > V_{11} > V_{14} > V_9 > V_8$ (Fig. 11).

Results revealed that various rice varieties and Cd levels showed significant variation (*p*≤0.01) for Fe concentration in root and shoot samples. Both the factors exhibited statistically significant results, while the interactive effect of both factors also showed significant results for the Fe concentration in root and shoots samples. Minimum Mn concentration in roots (4.03 mg kg^{-1} in V_8) was observed where the seedlings of rice varieties were dipped in only nutrient solution (control) followed by (15 µM), while maximum Fe concentration in roots (90.87 mg kg^{-1} in V_{15}) was noticed in where the rice seedling were dipped in solution having strength (10 µM). Minimum Fe concentration in shoots (0.06 mg kg^{-1} in V_9) was observed where the seedlings of rice varieties were dipped in only nutrient solution (control) followed by (5 µM), while maximum Fe concentration in shoots (28.74 mg kg^{-1} in V_8) was noticed in where the rice seedling were dipped in solution having strength (10 µM). The decreasing pattern in Fe concentration in roots and shoots for Cd levels was $T_3 > T_2 > T_1 > T_4$ and $T_3 > T_4 > T_1 > T_2$ while for rice varieties was $V_5 > V_{15} > V_{16} > V_{17} > V_1 > V_{13} > V_{11} > V_4 > V_2 > V_{12} > V_9 > V_{19} > V_3 > V_7 > V_{10} > V_{18} > V_{14} > V_6 > V_8 > V_{20}$ (Fig. 12), whereas, decreasing trend for shoot was $V_8 > V_6 > V_{14} > V_{16} > V_{20} > V_{18} > V_9 > V_{17} > V_{10} > V_{11} > V_4 > V_1 > V_{15} > V_3 > V_5 > V_{13} > V_7 > V_{12} > V_{19} > V_2$ (Fig. 13).

Discussion

The results for Cd accumulation in root and shoot are in line with Mehrag & Mark (1990) who documented that it is hard to differentiate the interaction of genotypic genes with the interaction of heavy metals under different environmental conditions. Plant environment and it's ecosystem severally effect on its growth and yield (Yang *et al*., 2023). Wu *et al*., (2006) demonstrated that absorption of Cd contents in rice exhibited a significantly positive relationship with the yield of grains and biomass. Due to the high activity of roots, in rice genotypes that showed tolerance towards Cd, Cd was absorbed in roots at first and increased the water usage/g of grain, whereas, Cd translocation and accumulation was decreased, in tolerant genotypes, towards parts situated above the ground. Parallel results were also exhibited by Adhikari *et al*., (2006). Furthermore, the plant's Cd tolerance can be linked to Cd dispersal exposure to Cd, plant ions, the metal movement towards shoots from roots, Cd formation and complex binding peptides in underground as well as above-ground parts (Arao *et al*., 2003).

The uptake of Cd was enhanced when Cd was applied at 15 µM and higher in the case of 10 µM application. The decreased dry weight of roots and shoots (bio concentration) might be the reason for this response. The concentration of Cd was impacted by the healthy establishment of root and shoot systems as a result exhibited high uptake. Our presented results are the same and in line with Adhikari *et al*., (2006) who documented that Cd uptake were more in tolerant genotypes which have good growth of roots as compared to poor growth of roots in sensitive genotypes.

Cd translocation was less than one in all mentioned rice varieties designated that Cd restricted in roots and its lower concentration was translocated towards shoots. This pattern altered with higher Cd application. Kabata-Pendias & Henryk (2000) documented that Cd movement in plants is narrowly associated with plants metabolism viz. metabolism with a high rate helps in the movement of Cd from underground to above ground parts. The current study revealed that it was a little bit impacted by the application of Cd concentrations, whereas the concentration of Cd was increased (denominator) in roots. Gaoxiang *et al*., (2017) documented after their experiment on brown rice that Cd transport from root to shoot was restricted by nodes. Results also in line with Yang *et al*., (2018) who observed that ability of Cd accumulation in various tissues of plants was more in roots followed by leaves and stems, while, also found that the translocation factor was below one.

Bioaccumulation of Cd was not observed in control. It might be due to reduced root growth activity as Cd added with higher concentration. Cd bioaccumulation was less than one in all mentioned rice varieties designated that Cd restricted in roots after absorption. Results were also in line with Yang *et al*., (2018) who observed that ability of Cd accumulation in various tissues of plants was more in roots followed by leaves and stems, while, also found that translocation factor was below one. In crux, stress due to application of Cd minimized the growth of shoots and roots. Less concentration of Cd was absorbed in Super Basmati (V1) as compared to tested varieties, might be due to poor activity of roots in media which contain high concentration of Cd, whereas other tested varieties reserved the Cd in their roots after absorption. Tested varieties viz. V1, V2, V4, V3 and V9 recommended if cultivated in Cd polluted soil, due to low level of Cd in shoots, whereas V20, V13 and V19 not recommended in this scenario for cultivation.

Significant impact of harmful metals exists on take-up and movement of minerals indifferent kinds of the soil just as plants that could be exploited the metals behavior with micronutrients in plants and soil (Nie *et al*., 2023). Different heavy metals that effect on the rice growth viz. Cu, Zn and Ni are familiar as indispensable plants micronutrients, whereas their higher contents could be harmful for organisms. Small concentration of zinc could significantly enhance the production of crop and play a vital role as mineral fertilizer, whereas its higher contents could lower the ending yield and production (Yang *et al.*, 2022). Hence, recommended that prime use of Zn as fertilizer, initially a trial conducted to assess the Zn level in irrigation water and soil of farm afore initiates sowing and fertilizing (Fathi *et al*., 2009).

The paramount concern relevant with contamination of Cd is its incidence as free ionic form. This dispensable component is up taken by numerous plant species and added throughout all parts comprising underground as well as above ground parts. Cohen *et al*., (1998) documented that deficiency of Fe induced an improved ability to absorb Fe, micronutrients and heavy metals viz. Cd^{2+} and Zn^{2+} in roots of pea plant (*Pisums ativum* L.). Rodecap *et al*., (1994) demonstrated that higher Cd contents, Mg in racemes and seeds accumulate in plants of Arabidopsis deficient with Fe as compared to plants that have sufficient Fe level. Cohen *et al*., (1998) observed that deficiency of Fe induces a divalent cation carrier that can facilitate Cd^{2+} influx. In rice, Cd concentration increased whereas Fe concentration decreased in both shoots and roots of rice seedlings treated with $CdCl_2$.

Cd toxicity significantly effect on the physiology of rice plant. It can enter in food chain and can cause severe health risk for human being. Garg & Bhandari (2016) reported that the Cd negatively effect on the uptake of Zn and Mn but Fe uptake improve in tomato plants. Cd toxicity inhibited the Zn and Mn translocation from root to shoot and increase Cd translocation towards the shoot in wheat plant. Cd toxicity can damage the nutrients homeostasis and disturbed whole plant physiology. These change in the crop physiological functions alter the different other internal processes (Zhang *et al*., 2023). Hasanuzzaman *et al*., (2019) also reported the Cd toxicity in rice plants, this study found that the Cd toxicity decreased the translocation of Zn and Mn from root to shoot and enhance Cd movement due to higher availability from the root zone. These trends of nutrients translocation can varies with the change of different crop varieties.

Competition theory was partially confirmed among Mn and Cd uptake after their analysis (Thomine *et al*., 2003). It was also noticed that the addition of Cd can reduced the levels of Mn and Zn significantly in barley shoots and roots as well as in rice (Wu *et al*., 2006). In the same way, Cd uptake and toxic impact can be significantly moderated when indispensable nutrients viz. Zn, Ca, Fe, Cu, Mn applied in higher concentration or dispensable one Ti. Higher concentration of Mn minimized the Cd uptake from nutrient medium, as a result exhibited reduced Cd in tissues of plant (Baszynski *et al*., 1980). Higher concentration in white lupine, Mn hyper accumulator, could take part to alleviate the Cd negative impact, particularly in photosynthesis (Wu *et al*., 2006). Cadmium accumulation was high in the leaf chloroplast as when Cd applied through growth media and also observed in lettuce. Furthermore, Cd damaged structure of chloroplast was partially restored after application of Mn (Thomine *et al*., 2003; Baszynski *et al*., 1980).

Conclusion

The present study revealed that, in the crux, cadmium along with its concentration impacted the rice varietal roots and shoots. Every variety exhibited a particular response, due to its root and shoots systems growth, towards the strength of Cd in terms of Cd concentration, its uptake, translocation, bioaccumulation, Zn, Mn, and Fe contents. A good root system absorbs much Cd concentration, whereas less concentration was translocate and accumulated in shoots. Higher concentrations of Cd can minimize the Zn, Mn, and Fe levels in roots and shoots of rice genotypes. In the future, study should be conducted to identify the genes that responsible for these fluctuations in rice germplasm.

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