

Impacts of cadmium on the growth, yield and mineral nutrition of boro rice (BRRI dhan28)

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Abstract

Cadmium (Cd) is a nonessential trace element in plants that is ubiquitous in the environment. Random disposal of urban and industrial refuses such as dyeing, spinning, tanning, smelting, mining, metal manufacturing, and application of synthetic phosphate fertilizers in cropping lands enhance the concentration of Cd in the soils, crops and its ultimate goal in the food chain which are carcinogenic to human health. A pot experiment has been undertaken to evaluate the effect of cadmium on the growth, yield, mineral nutrition and transfer of cadmium in the Boro rice (BRRI dhan28) crops. Boro rice was grown in untreated (control) and 03, 05, 07, 09, 15, 30, 60 and 90 mg/kg Cd as $3\text{CdSO}_4 \cdot 8\text{H}_2\text{O}$ treated soils. A significant reduction of fresh weight, dry weight and grain yield of BRRI dhan28 was initiated at 3mg/kg soil and with increasing successive application of cadmium; growth and yield of BRRI dhan28 rice plants reduced significantly. Similarly, with the increasing rate of cadmium application, a significant reduction of N, P, K, Ca and Mg was recorded from 3mg/kg to upwards. On the other hand, cadmium concentration in grains, straw and roots of rice increased with increased cadmium levels in soils. Cadmium concentration in the grains, straw and roots followed the order: Roots > Shoots > Grains and 3mg/kg soil was considered as threshold of cadmium toxicity of BRRI dhan28 rice variety. Plant died at 60 and 90 mg/kg doses of cadmium.

1. Introduction

Soils become contaminated by high concentration of metalloids and trace metals through random disposal of high metal wastes, pesticides, coal combustion residues, mine tailings, leaded gasoline, paint, synthetic fertilizers, manures, petrochemical spillage, sewage sludge, electroplating, batteries, welding, smelting, pigments, tanneries, textiles, chemicals, medicine and foods⁽¹⁻⁴⁾.

Among the trace metals, Cd is considered as ruthless, highly toxic to human and other living organisms and mobile metabolic element⁽⁵⁻⁹⁾. Cd²⁺ pollution is of increasing scientific

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interest, since it is readily taken up by the roots of many plant species⁽¹⁰⁾. Its toxicity is generally considered to be 2-20 times higher than other heavy metals⁽¹¹⁾ and 20 times more toxic than Pb. Cadmium is an important toxicant in affecting plant productivity⁽¹²⁻¹⁴⁾ and also has a long biological half-life⁽¹⁵⁾. Cadmium salts are highly water soluble and its ionic form is highly mobile within the phloem and, therefore, easily translocated to various plant species parts^(5,16). Although, Cd is not necessary element for plants, the plants absorb the element from soil and concentrate them into the different edible organs^(17,18). Cadmium disrupts water balance, photosynthesis, protein synthesis, and other key metabolic processes and even the death of plants^(19,20). Cadmium readily accumulates in rice tissues and exerts pronounced toxicity that disrupts cellular structures and ultimately impairing normal physiological functions and development processes. Under Cd stress, rice growth is markedly inhibited, leading to reduction in roots and shoot length as well as overall biomass production. These inhibitory effects intensify progressively with increased Cd concentrations⁽²¹⁻²⁴⁾. Cadmium in minerals replaces Ca^{2+} due to having identical charge, similar ionic radius and chemical behavior⁽²⁵⁾. Therefore, it can easily transfer to the human body and be stored in various organs at a high level⁽²⁶⁾. Toxicity of Cd causes serious damage to the liver and bones and at the same time, it reduces the uptake of Ca^{2+} in the human body⁽²⁷⁾. It was estimated that 70% of the Cd intake by the humans comes from plant foods⁽²⁸⁾.

So, the present study has been undertaken to study the effects of cadmium on the growth, yield, mineral nutrition and cadmium accumulation in of Boro rice (BRRI dhan28).

2. Materials and Methods

2.1 Materials

A pot experiment was conducted in the Nethouse, Department of Soil, Water and Environment, University of Dhaka, Dhaka-1000, Bangladesh in December- 2019. The experiment was done with BRRI dhan28, a boro rice variety (*Oryza sativa* L.) as a test crop in completely randomized design with three replications.

Soils for pot experiment were collected from the agricultural field of the village Sakrauri, Gazipur from 0 – 15 cm depth. Collected soils were air dried for several days and a portion of the soils were crushed and passed through 2.0 mm sieve and was kept in plastic container for physical and chemical analysis. The analytical results of the soils as collected for pot experiment are presented in table 1.

Table 1. Physicochemical characteristics of soil under study

No.	Parameters	Results
1	Texture	Silty clay loam
2	pH	5.64
3	EC ($\mu\text{S}/\text{cm}$)	30.0
4	Moisture (%)	0.51
5	Organic C (%)	1.04
6	Total N (%)	0.14
7	Total P (%)	0.05
8	Total Ca (meq/100 gm soil)	1.33
9	Total Mg (meq/100 gm of soil)	0.73
10	Total K (%)	0.25
11	Exchangeable- K (meq/100 gm of soil)	0.06
12	CEC (Cmoles/ kg soil)	2.94
13	Pb (mg/kg)	1.30
14	Zn (mg/kg)	30.0
15	Cu (mg/kg)	1.0
16	Ni (mg/kg)	0.50
17	Cd (mg/kg)	0.11

Setup of the pot culture experiment and treatment combination of metals

Seven kg of air-dried soils were taken in 10L sized plastic pot. A total of eight treatments were chosen with three replications each. The basal doses of fertilizers were Urea 245kg/ha, TSP 125 kg/ha, MP 150 kg/ha and gypsum 72 kg/ha according to fertilizer recommendation guide of BARC, Bangladesh. The date of transplanting the seedlings was 25.12.2019 and the harvesting date was 03.05.2020. The physical appearance of the 60 days old rice plants are shown in plate 1. Rice (BRRI dhan28) was grown by using eight Cd treatments, those of which were T₁(control), T₂(3 mgkg⁻¹ soil), T₃(5 mgkg⁻¹ soil), T₄(7 mgkg⁻¹ soil), T₅(9 mgkg⁻¹ soil), T₆(15 mgkg⁻¹ soil), T₇(30 mgkg⁻¹ soil), T₈(60 mgkg⁻¹ soil) and T₉(90 mgkg⁻¹ soil).

Finely powdered Cd salts were applied as 3CdSO₄, 8H₂O on the surface of the soil and was thoroughly mixed with it. Only the healthy, plump, large and uniform sized seedlings were selected for transplanting. 42 days old 3 seedlings per hill and 5 hills per pot were transplanted. The plants were watered daily evening with tap water maintaining 3cm above the soil surface throughout the growing period and the weeds were controlled by uprooting manually. Malathion 57EC (liquid) was sprayed to control cutworms. The straw and grains of rice crops were separated and stored in polythene bags. The roots of rice crops were washed with tap water and the fresh weight and dry rice grain weight were recorded. Straw

and roots of rice were air-dried and oven-dried at 70°C for 48 hours and then weighed and ground and stored in a plastic pot for chemical analysis.



Plate 1. The growth and physical appearance of boro rice (BRR1 dhan28) as affected by various levels of cadmium treatments.

2.2 Plant Sample Analysis

The total nitrogen (straw, grains and roots) was determined by Micro Kjeldahl's method following H_2SO_4 acid digestion and steam distillation with 40% NaOH as suggested by Jackson⁽²⁹⁾. The rice grains, straw and roots were digested with HNO_3 : HClO_4 (5:1) acid mixture for total analyses of P, Na, K, Ca, Mg and Cd⁽³⁰⁾. After developing the yellow color with vanadomolybdate, the total phosphorus of the crop samples was determined colorimetrically by using a spectrophotometer (Model: Jenway 6100) as described by Jackson⁽²⁹⁾. The intensity of the yellow color was measured at 470 nm wavelength.

Calcium, Mg and Cd of the grains, straw and roots of rice were determined by atomic absorption spectrophotometer (model: VARIAN- 220). Potassium was determined by using flame emission spectrophotometer (model: Jencons PEP 7) at 769 nm of wavelength⁽²⁸⁾. And every 10 ml sample was included as a certified reference material (CRM) to ensure QA/QC. All the analyses were done both in the Advanced Environmental Laboratory of the Department of Soil, Water and Environment, DU and Centre for Advanced Research of Science (CARS), DU.

2.3 Statistical analysis

The analytical results of the experiment were evaluated in computer with SPSS version -16 in the form of Duncan's Multiple Range Test (DMRT).

3. Results and Discussion

3.1 Fresh weight, dry weight and grain weight of BRR1 dhan28 as affected by Cd treatments

The growth and physical appearance of 60 days old rice (BRR1 dhan28) as affected by Cd and different levels of Cd treatments have been depicted in plate 1. The results pertaining to the effect of different concentrations of Cd on fresh biomass yield, dry matter yield and grain yield of rice (BRR1 dhan28) variety have been presented in table 2. The

highest yields of fresh matter, dry matter and grain yield production were obtained in control (T₁) where no Cd was applied. On the other hand, the lowest were found at T₇ treatment where 30 mg/kg soil Cd was applied. A significant yield reduction was initiated at T₂ treatment, where 3 mg/kg Cd was applied and the trend was continued upwards. The decrement of grain and straw production ranges from 13.87 to 76.62 and 9.65 to 73.60 percent respectively as compared to the control. The highest yield reduction was obtained in T₇ treatment where 30 mg/kg soil Cd was applied. But at the T₈ and T₉ treatments, where 60 and 90 mg Cd/kg soil were applied, plant death occurred. According to Munir *et al.*⁽³¹⁾, Cd toxicity in plants can cause poor seed germination, inhibition of photosynthesis, breaking of chloroplast ultrastructure and inhibition of plant growth which may lead to plant death⁽²⁰⁾. Kuzovkina *et al.*⁽¹⁹⁾ mentioned that Cd could be strongly phytotoxic causing rapid death of plant.

Table 2. Fresh and dry weight and grain yield (g/pot) of rice (BRRI dhan28) as affected by different doses of cadmium

Treatments of Cd	Yield parameters		
	Fresh weight (g/pot)	Dry weight (g/pot)	Grain weight (g/pot)
T ₁ :control	145.33 a	30.05 a	44.91 a
T ₂ :3 mgkg ⁻¹ soil	131.30 b	27.10 b	38.68 b
T ₃ : 5 mgkg ⁻¹ soil	120.25 c	24.20 c	35.13 c
T ₄ : 7 mgkg ⁻¹ soil	109.30 d	21.70 d	28.77 d
T ₅ : 9 mgkg ⁻¹ soil	95.67 e	18.50 e	24.47 e
T ₆ : 15 mgkg ⁻¹ soil	55.50 f	11.56 f	15.02 f
T ₇ : 30 mgkg ⁻¹ soil	38.36 g	8.37 g	10.50 g
T ₈ : 60 mgkg ⁻¹ soil	-	-	-
T ₉ : 90 mgkg ⁻¹ soil	-	-	-

Mean value in the same column with the same letters(s) did not vary significantly ($p = 0.05$) by DMRT

Kibria *et al.*⁽³²⁾ and Muramoto *et al.*⁽³³⁾ found that biomass production of rice was significantly affected by cadmium treatment. Grain, straw and root weight of rice were reduced by the application of different levels of cadmium as compared to that of control. Chen⁽³⁴⁾ considered 3 mg/kg soil cadmium as contaminated soil. Liu *et al.*⁽³⁵⁾ suggested that brown and polished rice is Cd-contaminated when the soil Cd-concentration is higher than 2 mg/kg. Liu *et al.*⁽³⁶⁾ observed that 50 mg/kg cadmium in soils stunted growth of rice. Bringham *et al.*⁽³⁷⁾ observed that Cd concentration (<3ppm) in edible tissue of greenhouse soil-grown plants reduced 50% yield of field bean, paddy rice, upland rice and sweet corn. Cadmium diminishes the elongation of both shoot and root, and dry matter production by plants, primarily due to hamper of photosynthetic activity⁽³⁸⁾.

Wahid *et al.*⁽²⁰⁾ reported that cadmium toxicity reduced growth, and yield of plants. Verma and Dubey⁽³⁹⁾ reported declined growth and yield of plants with elevated levels of cadmium in growth media. Haghiri⁽⁴⁰⁾ noted that Cd toxicity in soybean and wheat begun to occur at soil Cd levels as low as 2.5 ppm (soil pH 6.7). Padmaja *et al.*⁽⁴¹⁾ stated that the reduction of biomass by Cd toxicity could be the direct consequence of inhibition of chlorophyll synthesis and photosynthesis.

Several researchers^(20,42-44) revealed that Cd toxicity reduced growth, and yield of plants. Padmaja *et al.*⁽⁴¹⁾ stated that the reduction of biomass of plants was directly associated with Cd toxicity. Similar results were also observed by Verma and Dubey⁽³⁹⁾. They reported that with elevated levels of Cd in growth media declined the growth and yield of plants. In addition, Cd diminishes the elongation of both shoot and root, and dry matter production by plants, primarily due to hamper of photosynthetic activity as stated by Azevedo *et al.*⁽³⁸⁾. Liu *et al.*⁽³⁶⁾ reported that 50 mg/kg Cd concentration in soils effectively inhibited rice growth and reduced rice grain yield substantially. Accordingly, Kuzovkina *et al.*⁽¹⁹⁾ revealed that Cd was strongly phytotoxic and caused rapid death of plants.

Cadmium induced leaf chlorosis due to antagonistic effect of cadmium on the uptake of iron, phosphorus, manganese, zinc and copper, causing their deficiencies particularly in the cadmium sensitive varieties⁽⁴⁵⁻⁴⁷⁾. It appears that the same metal transporters are employed for Cd as for other metal ions⁽⁴⁸⁾. Root membrane transporters involved in uptake of K, Ca and Mg are the first targets of cadmium toxicity⁽¹⁶⁾.

3.2 Mineral nutrition

Mineral nutrients in grains, straw and roots of rice (BRRI dhan28) as affected by Cd stress varied differently. Nitrogen in grains, straw and roots ranged from 1.12 - 1.88, 1.09 - 1.55 and 0.49 - 0.95% respectively; Phosphorus 0.17 - 0.49, 0.17 - 0.41 and 0.07 - 0.23% respectively; Potassium 1.54 - 2.53, 1.10 - 1.71 and 0.15 - 0.37% respectively; Calcium 0.20 - 0.52, 0.51 - 0.85 and 0.09 - 0.28% respectively and Magnesium 0.31 - 0.67, 0.42 - 0.70 and 0.07 - 0.24% respectively, which are presented in table 2. The highest amounts of all mineral contents were found at control (T₁) and decreased significantly with an increased in Cd levels (T₂, T₃, T₄, T₅, T₆) in soils. The lowest mineral contents were found at T₇ treatment where 30 mg/kg Cd was applied. And, at T₈ and T₉ levels of Cd application, where 60 and 90 mg Cd/kg soils were applied, plant death occurred.

Table 3. N, P, K, Ca and Mg concentrations in grain, straw and root of boro rice (BRRI dhan28) rice variety as affected by different levels of cadmium

Treatments of Cd	% N			%P			%K			%Ca			%Mg		
	Grains	Straw	Roots												
T ₁ : control	1.88a	1.55a	0.95a	0.49a	0.41a	0.23a	2.53a	1.71a	0.37a	0.52a	0.85a	0.28a	0.67a	0.70a	0.24a
T ₂ : 3 mgkg ⁻¹ soil	1.74b	1.46b	0.91b	0.32b	0.34b	0.18b	2.37b	1.54b	0.32b	0.44b	0.77b	0.19b	0.62b	0.66b	0.19b
T ₃ : 5 mgkg ⁻¹ soil	1.64c	1.39c	0.87c	0.30c	0.31c	0.17c	2.19c	1.48c	0.31c	0.38c	0.72c	0.17c	0.57c	0.64c	0.16c
T ₄ : 7 mgkg ⁻¹ soil	1.54d	1.36d	0.83d	0.27d	0.27d	0.14d	2.10d	1.42d	0.28d	0.35d	0.67d	0.15d	0.54d	0.58d	0.13d
T ₅ : 9 mgkg ⁻¹ soil	1.42e	1.29e	0.74e	0.23e	0.23e	0.12e	1.98e	1.36e	0.23e	0.31e	0.65e	0.14e	0.49e	0.55e	0.11e
T ₆ : 15 mgkg ⁻¹ soil	1.26f	1.17f	0.58f	0.20f	0.20f	0.09f	1.79f	1.28f	0.18f	0.26f	0.56f	0.10f	0.39f	0.48f	0.09f
T ₇ : 30 mgkg ⁻¹ soil	1.12g	1.09g	0.49g	0.17g	0.17g	0.07g	1.54g	1.10g	0.15g	0.20g	0.51g	0.09g	0.31g	0.42g	0.07g
T ₈ : 60 mgkg ⁻¹ soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T ₉ : 90 mgkg ⁻¹ soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Mean values with the same letters in the same column are not significantly different ($p = 0.05$) by DMRT

The result is in agreement with the findings of Vijayarengan⁽¹¹⁾ and Shukla *et al.*⁽⁴⁰⁾, Drazic *et al.*⁽⁴⁹⁾, Adhikari *et al.*⁽⁵⁰⁾, Ghnaya *et al.*⁽⁵¹⁾ and Wahid *et al.*⁽¹⁴⁾. They observed that nitrogen, phosphorus, potassium, calcium and magnesium contents in the grains, straw and roots of rice decreased with respect to the increased cadmium concentrations. Gomes *et al.*⁽⁵²⁾ reported that the uptake of nitrogen from soil is inhibited by the presence of heavy metals. Excessive amounts of cadmium in plant lead to a substantial diminution of total protein⁽⁵³⁾. Similarly, Ghani⁽⁵⁴⁾ observed significant decrement of growth and protein content in *Zea mays*.

Cunningham⁽⁵⁵⁾ and Iwai *et al.*⁽⁵⁶⁾ also observed that cadmium depressed Ca, Mg and N uptake in plant. Shukla *et al.*⁽⁴⁰⁾; Drazic *et al.*⁽⁵⁰⁾, Wahid *et al.*⁽¹⁴⁾ and Adhikari *et al.*⁽⁵⁰⁾ observed that with increasing cadmium levels in soils increased the cadmium concentrations in plants, but phosphorus contents in different parts of plants decreased. Several scientists agreed with the statement that cadmium has an antagonistic effect on the uptake of Fe, P, Mn, Zn and Cu causing their deficiencies particularly in the cadmium-sensitive varieties⁽⁴⁵⁻⁴⁷⁾.

Vijayarengan⁽¹¹⁾ found an antagonistic effect of Cd on K uptake in rice. Likewise, Gussarsson⁽⁵⁷⁾ reported that Cd reduced K uptake in *Betula pendula*. Vijayarengan⁽¹¹⁾ and Bonnet *et al.*⁽⁵⁸⁾ found an antagonistic effect of calcium with Cd in rice and Stoyanova and Doucheva⁽⁵⁹⁾ observed it in zinc. Mengel *et al.*⁽¹⁶⁾ reported that root membrane transports involved in the uptake of K, Ca and Mg are the first target of cadmium toxicity. The decrease in calcium content in excess of these metals might be due to antagonistic action of calcium with cadmium. Lindon and Henriques⁽⁶⁰⁾ and Ouzounidou⁽⁶¹⁾ found that calcium and magnesium content decreased under copper treatment; Bonnet *et al.*⁽⁵⁸⁾ and Stoyanova and Doncheva⁽⁵⁹⁾ found it under zinc treatment. Similarly, Dinev and Stancheva⁽⁶²⁾ found it under aluminium treatment and Vijayarengan⁽¹¹⁾ and Gussarsson⁽⁵⁷⁾ under cadmium treatment. Agarwal *et al.*⁽⁶³⁾ reported that the increased cadmium treatments decreased magnesium content which might be due to the replacement of magnesium from the chlorophyll by the metals. It is important to note that the elevated Cd levels substantially influence plant mineral nutrition, and a negative correlation remained in the uptake and distribution of various macro and micro-nutrients in different plant parts^(14,40,49-51).

3.3 Cadmium contents in the grain, straw and root of rice (BRRI dhan28) as affected by cadmium

Cadmium concentration in the grains, straw and roots of rice (BRRI dhan28) rice as affected by different levels of Cd are presented in table 4 and figure 1.

The mean values of Cd concentration in the grains, straw and roots of rice (BRRI dhan28) ranged from 0.02 to 3.51 mg/kg, 0.30 to 29.30 mg/kg and 1.64 to 211.65 mg/kg, respectively.

Cd concentrations in grains, straw and roots increased considerably and significantly with increasing Cd application over control. However, Cd contents in the grains, straw and roots of control (T₁) and T₂ - T₇ treatments were found significantly different from each other. But, at treatments T₈ and T₉ where 60 and 90 mg Cd/kg soil were applied, plant death occurred. Cadmium negatively impacts rice crops by reducing growth and biomass, interfering with essential nutrient uptake, damaging photosynthetic processes, and increasing oxidative stress, leading to reduced yield and potentially causing plant death under severe conditions.

It was observed from the above discussions that the fresh weight, dry weight and grain yield of rice had been significantly and increasingly affected with increasing Cd treatments. Conversely, an increasing trend of Cd was found concentration increased significantly with increasing Cd levels in soils. On the other hand, the transfer co-efficient of Cd in grains, straw and roots of rice from soil ranged from 0.09 to 0.19, 0.90 to 1.58 and 6.67 to 14.28, respectively. And, the bulk of the Cd remained in the roots of rice crops. However, Cd contents in different parts of rice exhibited the following descending order: Root > Straw > Grain.

Table 4. Cadmium concentration in the grain, straw and roots of BRRI dhan28 as affected by different doses of cadmium

Treatments of Cd	Cd Concentrations					
	Grain		Straw		Root	
	Conc. (mgkg ⁻¹ DW)	TC	Conc. (mgkg ⁻¹ DW)	TC	Conc. (mgkg ⁻¹ DW)	TC
T ₁ : control	0.00a	-	0.30a	-	1.64a	-
T ₂ : 3 mgkg ⁻¹ soil	0.42b	0.14	4.73b	1.58	42.74b	14.28
T ₃ : 5 mgkg ⁻¹ soil	0.53c	0.11	6.81c	1.36	53.92c	10.77
T ₄ : 7 mgkg ⁻¹ soil	0.62d	0.09	7.87d	1.12	63.62d	9.09
T ₅ : 9 mgkg ⁻¹ soil	1.14e	0.13	8.98e	1.00	77.03e	8.56
T ₆ : 15 mgkg ⁻¹ soil	2.86f	0.19	13.47f	0.90	100.00f	6.67
T ₇ : 30 mgkg ⁻¹ soil	3.51g	0.12	29.30g	0.98	211.65g	7.05
T ₈ : 60mgkg ⁻¹ soil	-	-	-	-	-	-
T ₉ : 90 mgkg ⁻¹ soil	-	-	-	-	-	-

*TC means transfer co-efficient; Mean values with the same letters(s) in the same column did not vary significantly (p = 0.05)

The results were in accordance with the findings of several researchers^(11,32,64). They found an increasing trend of Cd concentration in rice with increasing Cd application. Vijayarengan⁽¹¹⁾ conducted a pot experiment with various levels of exogenous Cd (0, 10, 20, 30, 40, 50 mg/kg soil) and found that the accumulation of Cd in rice plants increased with an increase in Cd in soil at all levels. On the other hand, Jiang *et al.*⁽⁶⁵⁾ revealed that Cd accumulation in both shoots and roots of Indian mustard increased with increasing soil Cd treatments. Generally, Cd is taken up through the roots and it can be translocated to shoots, grains and fruits⁽⁶⁶⁾, but maize roots have a great ability to retain Cd⁽⁶⁷⁾. Kibria *et al.*⁽³²⁾ reported that Cd concentrations in different plant parts followed the order: Grain < Shoot < Root. In addition, Shaw and Panigrahi⁽⁶⁸⁾ and Fergusson⁽⁶⁹⁾ also reported more elaborately that the concentration level of a metal generally decreases in the following order: Root > Stem > Leaves > Fruit > Seed, when the source of metal is only the soil. Similar results were also revealed by Ullah *et al.*⁽⁷⁰⁾ and Vijayarengan⁽¹¹⁾. They observed that rice accumulated more metals in roots than in straws. Adriano⁽⁷¹⁾ stated that the total soil Cd concentration could not be considered reliable to determine whether rice grains are safe for consumers.

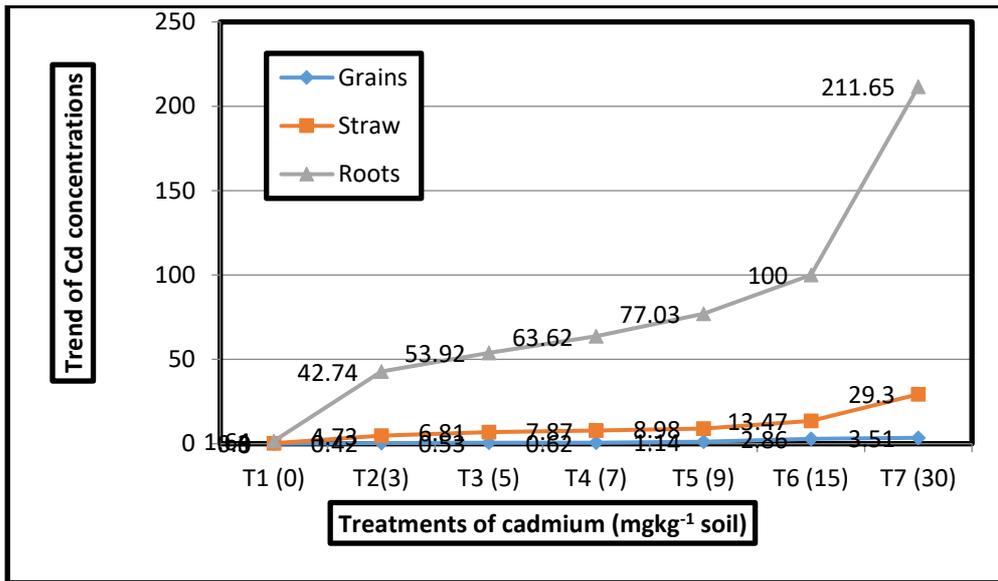


Fig. 1. Trend of Cd concentrations in grains, straw and roots of BRR1 dhan28 rice as affected by different levels of Cd.

4. Conclusion

From the present investigation, it can be concluded that the cadmium at all the levels tested (3-90 mg/kg) decreased fresh weight, dry weight and grain yields of rice (BRR1 dhan28). The nutrients contents (nitrogen, phosphorus, potassium, calcium and magnesium) in the grains, straw and roots of rice decreases with successively increased cadmium application. And, 3mg/kg soil cadmium was considered as the threshold value in soils as the significant effect was initiated at that level in soil. The concentrations of Cd in grains, straw and roots followed the order: Roots > Shoots > Grains and at higher concentrations (60 and 90 mg/kg soil) plant death occurred. These findings highlight the urgent need to monitor Cd levels in agricultural soils in Bangladesh to ensure rice safety and protect human health.

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