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Influence of Cadmium on Growth and Nutrients Content of Three Rice Cultivars

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Abstract: *A pot experiment was conducted at the net house of the Department of Agricultural Chemistry of Sher-e-Bangla Agricultural University, Dhaka-1207 from November, 2015 to May, 2016 to evaluate the influence of cadmium on growth and nutrients content of Boro rice cultivars. The two factorial experiment was laid out in a completely randomized design (CRD) with three replications. Factor A: three varieties [V_1-BRRI dhan29, V_2-BRRI dhan60 and V_3-BRRI dhan61] and factor B: five doses of cadmium [T_0= No cadmium applied, T_1= 20 ppm Cd, T_2=40 ppm Cd, T_3=60 ppm Cd, T_4=80 ppm Cd]. Cadmium was added from cadmium sulphate ($3CdSO_4.8H_2O$) and soils were treated with Cd as per treatments before transplanting. At 75 DAT and the time of harvesting, the highest plant height (87.80 cm and 94.33 cm, respectively) was observed from the V_2T_0 treatment whereas the lowest (53.67 cm and 67.30 cm, respectively) was observed from V_1T_4 treatment. At 75 DAT, the highest number of tillers hill^{-1}(19.67) was found from the V_3T_0 treatment whereas, the lowest (7.00) was found from V_1T_4. At the time of harvesting, V_1T_0 gave the miximum (34.33) and V_2T_4 gave the minimum (19.00) number of tillers hill^{-1}. At 45 DAT and 75 DAT, the highest number of leaves hill^{-1} (50.33 and 103.3, respectively) was recorded from the V_3T_0 treatment whereas, the lowest (16.33) was recorded from V_1T_4 treatment at 45 DAT and the lowest (53.00) was observed from V_2T_4 treatment at 75 DAT. Interaction of BRRI dhan61 and the treatment with no cadmium (T_0) gave higher K content in straw (5.137 %) and root (0.8133 %). Interaction of BRRI dhan60 and the treatment with no cadmium (T_0) gave higher Na content in straw (1.833 %) and root (1.430 %). Interaction of BRRI dhan61 and the treatment with no cadmium (T_0) gave higher Ca content in straw (0.559 %) while interaction of BRRI dhan60 and the treatment with no cadmium (T_0) gave higher Ca content in root (0.346 %). The Cd concentration in straw and root of three rice varieties increased with increasing rate of Cd addition. Almost all the growth characters and nutrients content were significantly decreased by cadmium contamination.*

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I. Introduction

Rice is the seed of the grass species *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice) and belongs to the cereal crops under Poaceae family.As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population, especially in Asia. It is the agricultural commodity with the third-highest worldwide production, after sugarcane and maize[1]. It is the staple food of Bangladesh. Bangladesh is an agro-based country with population of about 160 millions living in 14.84 million hectares of land. Rice is the staple dietary item for the people and per capita rice consumption in Bangladesh is about 166 kg/year[2]. Rice covers about 75% of the total cropped area[3]. Rice alone shares about 96% of the total cereal food supply. On the other hand, the need for increasing rice production is mounting up to feed the ever-increasing population of this country. Variety is the most important factor in rice production. Variety is the key component to produce higher yield of rice depending upon their differences in genotypic characters, input requirements and response, growth process and off course the prevailing environmental conditions during the growing season. The growth process of rice plants under a given agro-climatic condition differs with variety. Cadmium is a class one carcinogenic element in nature and is non-degradable contaminant which can be transferred from soil to plants[4]. Its accretion in crops and soils is an increasing concern to crop production[5]. A part of agricultural soils, all over the world are slightly to moderately polluted by Cd due to industrial pollution, metal mining, manufacture and disposal as well as some agricultural practices such as extended use of superphosphate fertilizers, pesticides, sewage sludge and smelters dust spreading leads to dispersion of Cd[6]. The cadmium treatment led to an inhibition of growth rate, transpiration and ion uptake by wheat seedlings; the rapid inhibition of root function was evident in terms

of reductions in both ion and water uptake and the decrease in transpiration of Cd - treated plants is likely to be due to stomata closure[7]. Cd-induced reduction in stomata conductivity is in accordance with the literature[8]. Its physiological significance might be in limiting water losses when water uptake by roots is reduced by Cd. Cadmium is highly toxic to human, animals and plants. In plants exposure to Cd causes reductions in photosynthesis, water and nutrient uptake[9]. Cadmium contamination in rice grain is a serious threat to human health especially for those with a rice based food diet. In this aspect, the present experiment was undertaken to study the interactive effect of variety and different cadmium doses on growth and nutrients contents of three rice cultivars.

II. Materials and methods

The pot experiment was carried out during the Boro season of November, 2015 to May, 2016 to evaluate the effect of cadmium on rice at the net house of Agro-Environmental Chemistry laboratory of the department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The pots were prepared according to Razzaque MA *et al.* (2010)[10] There were altogether 45 pots comprising 5 different treatments *viz.* 0, 20, 40, 60 and 80 ppm Cd (on soil weight basis) to three different boro rice varieties *viz.* BRRI dhan29, BRRI dhan60 and BRRI dhan61 with 3 replications. The source of Cd was Cadmium Sulphate ($3CdSO_4.8H_2O$). The data were compiled and tabulated in proper form, K, Na Ca content of the straw and root were determined using flame photometer (Jenway, PFP7) and Cd content was determined using atomic absorption spectrophotometer (Analytik Jena novAA 400 P) and were subjected to statistical analysis. Analysis of variance was done following the computer package MSTAT-C program developed[11]. The mean differences among the treatments were adjusted by least significant difference (LSD) test at 5% level of significance[12].

III. Results And Discussion

Plant height

Interaction effect of varieties and different cadmium doses showed significant variation on plant height of rice at 45 DAT, 75 DAT and at the time of harvesting (Table 1). At 45 DAT, the highest plant height (46.00 cm) was observed from the V_1T_0 treatment which was statistically similar with V_3T_0 (45.93 cm), V_1T_1 (42.67 cm), V_2T_0 (43.10 cm) whereas, the lowest (26.67 cm) was observed from V_2T_4 treatment which was statistically similar withV_3T_4 (26.93 cm), V_1T_4 (29.33 cm). At 75 DAT, the highest plant height (87.80 cm) was observed from the V_2T_0 treatment which was statistically similar to V_3T_0 (85.67 cm) whereas, the lowest (53.67 cm) was observed from V_1T_4 treatment which was statistically similar with V_1T_3 (57.67 cm). At the time of harvesting, the highest plant height (94.33 cm) was observed from the V_2T_0 treatment which was statistically similar to V_1T_0 (92.60 cm) whereas, the lowest (67.30 cm) was observed from V_1T_4 treatment which was statistically similar to V_3T_4 (68.40 cm). This finding supports the experiment using six rice cultivars with 100 mg kg^{-1} soil Cd and concluded that toxicity effect of Cd on plant height is varietal dependent[13].

Table 1. Interaction effect of varieties and cadmium doses on plant height at different days after transplanting

Treatment		Plant Height (cm)		
		45 DAT	**75 DAT**	**At harvest**
V_1	T_0	46.00 a	75.60 ef	92.60 ab
	T_1	42.67 ab	71.87 fg	82.40 cd
	T_2	38.33 cde	61.93 i	78.53 e
	T_3	35.00 ef	57.67 j	71.47 g
	T_4	29.33 hi	53.67 j	67.30 h
V_2	T_0	43.10 ab	87.80 a	94.33 a
	T_1	40.30 bc	83.50 bc	90.67 b
	T_2	36.00 def	75.27 ef	84.67 c
	T_3	33.00 fg	69.77 g	79.00 e
	T_4	26.67 i	65.33 hi	75.00 f
V_3	T_0	45.93 a	85.67 ab	90.43 b
	T_1	39.10 cd	80.67 cd	82.70 cd
	T_2	34.97 ef	77.33 de	79.87 de
	T_3	31.00 gh	72.33 fg	74.67 f
	T_4	26.93 i	68.33 gh	68.40 h
$LSD_{(0.05)}$		**3.402**	**4.182**	**3.048**
Significant level		*	*	*
CV (%)		**5.56**	**3.45**	**2.26**

V_1 – BRRI dhan29, V_2 – BRRI dhan60, V_3 – BRRI dhan61
T_0= No cadmium applied, T_1= 20 ppm Cd,T_2= 40 ppm Cd, T_3= 60 ppm Cd, T_4= 80 ppm Cd
*Significant at 5% level

Number of tillers hill^{-1}

Interaction effect of varieties and different cadmium doses showed significant variation on number of tillers hill^{-1} of rice at 45, 75 DAT and at the time of harvesting (Table 2). At 45 DAT, the highest number of tillers hill^{-1} (13.67) was observed from the V_3T_0 treatment which was statistically similar to V_2T_0 (13.33), V_2T_1 (11.67) and V_3T_1 (11.67) whereas, the lowest (4.00) was observed from V_1T_4 treatment which was statistically similar to V_1T_3 (5.00), V_2T_4 (5.33) and V_3T_4 (5.33). At 75 DAT, the highest number of tillers hill^{-1}(19.67) was observed from the V_3T_0 treatment which was statistically similar to V_1T_0 (18.67) whereas, the lowest (7.00) was observed from V_1T_4 treatment which was statistically similar to V_3T_4 (8.00) and V_2T_4 (8.33). At the time of harvesting, the highest number of tillers hill^{-1} (34.33) was observed from the V_1T_0treatment which was statistically similar with V_3T_0 (32.67) and V_1T_1 (31.33) whereas, the lowest (19.00) was observed from V_2T_4 treatment which was statistically similar with V_3T_4 (19.33), V_2T_3 (21.67) and V_1T_4 (22.00). Herath *et al.* (2014)[14] also found the interaction effect in a pot experiment which was conducted to investigate the variations of plant growth and levels of accumulation of Cd among eight rice genotypes (new improved varieties-NIVs and traditional varieties- TVs) grown under different soil Cd levels.

Table 2. Interaction effect of varieties and cadmium doses on number of tillers hill^{-1}at different days after transplanting

Treatment		Number of tillers hill^{-1}		
		45 DAT	**75 DAT**	**At harvest**
V_1	T_0	11.33 bcd	18.67 a	34.33 a
	T_1	8.33 ef	15.00 b	31.33 ab
	T_2	6.67 fg	12.00 cd	26.00 de
	T_3	5.00 gh	9.67 e	22.67 efgh
	T_4	4.00 h	7.00 f	22.00 fghi
V_2	T_0	13.33 ab	15.67 b	30.00 bc
	T_1	11.67 abc	13.67 bc	25.67 de
	T_2	10.00 cde	12.33 c	23.00 efg
	T_3	8.00 ef	10.00 de	21.67 ghi
	T_4	5.33 gh	8.33 ef	19.00 i
V_3	T_0	13.67 a	19.67 a	32.67 ab
	T_1	11.67 abc	15.33 b	27.67 cd
	T_2	9.33 de	12.33 c	25.33 def
	T_3	7.00 fg	9.33 e	23.67 efg
	T_4	5.33 gh	8.00 ef	19.33 hi
LSD $_{(0.05)}$		**2.183**	**2.013**	**3.487**
Significant level		*	*	*
CV (%)		**14.98**	**9.65**	**8.14**

V_1 – BRRI dhan29, V_2 – BRRI dhan60, V_3 – BRRI dhan61
T_0= No cadmium applied, T_1= 20 ppm Cd,T_2= 40 ppm Cd, T_3= 60 ppm Cd, T_4= 80 ppm Cd
*Significant at 5% level

Number of leaves hill^{-1}

Interaction effect of varieties and different cadmium doses showed significant variation on number of leaves hill^{-1} of rice at 45 and 75 DAT (Table 3). At 45 DAT, the highest number of leaves hill^{-1} (50.33) was observed from the V_3T_0 treatment whereas, the lowest (16.33) was observed from V_1T_4 treatment. The highest number of leaves hill^{-1} (103.3) was observed from the V_3T_0 treatment whereas, the lowest (53.00) was observed from V_2T_4 treatment at 75 DAT.

Table 3. Interaction effect of varieties and cadmium doses on number of leaves hill^{-1} at different days after transplanting

Treatment		Number of leaves hill^{-1}	
		45 DAT	**75 DAT**
V_1	T_0	40.33 c	97.00 b
	T_1	30.00 ef	87.67 c
	T_2	25.67 g	79.67 d
	T_3	20.67 h	73.67 e
	T_4	16.33 i	67.00 gh
V_2	T_0	43.33 bc	73.00 ef
	T_1	41.00 c	68.00 fgh
	T_2	34.33 d	64.67 h
	T_3	30.33 ef	59.00 i
	T_4	27.00 fg	53.00 j

V_3	T_0	50.33 a	103.3 a
	T_1	46.33 b	87.33 c
	T_2	39.67 c	77.00 de
	T_3	33.67 de	72.00 efg
	T_4	29.67 f	65.33 h
LSD (0.05)		**3.860**	**5.375**
Significant level		*	*
CV (%)		**6.81**	**4.27**

V_1 – BRRI dhan29, V_2 – BRRI dhan60, V_3 – BRRI dhan61
T_0= No cadmium applied, T_1= 20 ppm Cd,T_2= 40 ppm Cd, T_3= 60 ppm Cd, T_4= 80 ppm Cd
*Significant at 5% level

Number of effective tillers hill^{-1}

Interaction of varieties and different doses of cadmium showed significant variation on the number of effective tillers hill^{-1} of rice (Table 4). The highest number of effective tillers hill^{-1} (29.00) was observed from the V_3T_0 treatment which was statistically similar with V_1T_0 (26.67) whereas, the lowest (10.00) was observed from V_2T_4 treatment which was statistically similar with V_1T_4 (11.00) and V_3T_4 (11.67). Number of effective tillers hill^{-1} can vary from cultivar to cultivar.

Number of non-effective tillers hill^{-1}

Number of non-effective tillers hill^{-1} was significantly varied due to interaction of varieties and different cadmium doses at all growth stages (Table 4). The highest number of non-effective tillers hill^{-1} (11.00) was recorded from treatment combination V_1T_4 which was statistically similar with V_1T_3 (9.33) In contrast, the lowest number of non-effective tillers hill^{-1} (3.67) was recorded from the treatment combination V_3T_0 which was statistically similar withV_3T_1 (9.33) and V_3T_2 (5.33).

Table 4. Interaction effect of varieties and cadmium doses on number of effective and non-effective tillers hill^{-1}

Treatment		Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}
V_1	T_0	26.67 ab	8.67 bc
	T_1	22.33 cd	9.00 b
	T_2	18.00 ef	8.00 bcd
	T_3	13.67 gh	9.33 ab
	T_4	11.00 hi	11.00 a
V_2	T_0	23.33 c	6.67 de
	T_1	19.33 de	6.33 de
	T_2	16.00 fg	7.00 cde
	T_3	13.67 gh	8.00 bcd
	T_4	10.00 i	9.00 b
V_3	T_0	29.00 a	3.67 f
	T_1	24.00 bc	3.67 f
	T_2	20.00 de	5.33 ef
	T_3	16.00 fg	7.67 bcd
	T_4	11.67 hi	7.67 bcd
LSD (0.05)		**3.016**	**1.739**
Significant level		*	*
CV (%)		**9.85**	**14.05**

V_1 – BRRI dhan29, V_2 – BRRI dhan60, V_3 – BRRI dhan61
T_0= No cadmium applied, T_1= 20 ppm Cd,T_2= 40 ppm Cd, T_3= 60 ppm Cd, T_4= 80 ppm Cd
*Significant at 5% level

Nutrients content

K content

K content in straw and root varied significantly due to the interaction effect of variety and different cadmium doses and (Table 5). The highest K content in straw and root (5.137% and 0.813%, respectively) was observed from V_3T_0 while the lowest result (1.673% and 0.337%, respectively) was recorded from V_1T_4 which was statistically similar with V_1T_3 (0.34%), V_1T_2 (0.363%) and V_1T_1 (0.377%) in case of root.

Table 5. Interaction effect of variety and cadmium on potassium content in straw and root

Treatment		Potassium content (% K)	
		Straw	**Root**
V_1	T_0	2.333 h	0.427 fg
	T_1	2.147 i	0.377 gh
	T_2	2.120 i	0.363 h
	T_3	1.760 j	0.340 h
	T_4	1.673 k	0.337 h

V_2	T_0	3.570 c	0.573 c
	T_1	3.523 c	0.477 def
	T_2	2.903 e	0.480 de
	T_3	2.800 f	0.447 ef
	T_4	2.660 g	0.427 fg
V_3	T_0	5.137 a	0.813 a
	T_1	4.830 b	0.643 b
	T_2	3.420 d	0.630 b
	T_3	2.920 e	0.563 c
	T_4	2.143 i	0.523 cd
LSD $_{(0.05)}$		**0.052**	**0.052**
Significant level		*	*
CV (%)		**0.45**	**2.29**

V_1 – BRRI dhan29, V_2 – BRRI dhan60, V_3 – BRRI dhan61

T_0= No cadmium applied, T_1= 20 ppm Cd,T_2= 40 ppm Cd, T_3= 60 ppm Cd, T_4= 80 ppm Cd

Sodium content

Na content in straw and root varied significantly due to the interaction effect of variety and different cadmium doses and (Table 6). The highest Na content in straw (1.833%) was observed from V_2T_0, while the lowest result (0.620%) was recorded from V_1T_4 which was statistically similar with V_1T_3 (0.657%). In case of root, the highest Na content (1.430%) was observed from V_2T_0 which was statistically similar with V_3T_0 (1.377%), V_3T_1 (1.353%), V_1T_0 (1.353%), V_2T_1 (1.290%), V_3T_2 (1.263%) and V_3T_3 (1.197%), while the lowest result (0.727%) was recorded from V_1T_4 which was statistically similar with V_1T_3 (0.810%), V_2T_2 (0.813%), V_1T_2 (0.853%) and V_1T_1 (0.907%).

Table 6. Effect of combination of variety and cadmium on sodium content in straw and root

Treatment		**Sodium content (% Na)**	
		Straw	**Root**
V_1	T_0	0.953 i	1.353 abc
	T_1	0.860 j	0.907 efg
	T_2	0.740 k	0.853 fg
	T_3	0.657 l	0.810 g
	T_4	0.620 l	0.727 g
V_2	T_0	1.833 a	1.430 a
	T_1	1.447 d	1.290 a-d
	T_2	1.330 e	0.813 g
	T_3	1.290 ef	1.107 cde
	T_4	1.250 fg	1.070 def
V_3	T_0	1.770 b	1.377 ab
	T_1	1.617 c	1.353 abc
	T_2	1.453 d	1.263 a-d
	T_3	1.213 gh	1.197 a-d
	T_4	1.163 h	1.163 bcd
LSD $_{(0.05)}$		**0.052**	**0.248**
Significant level		*	*
CV (%)		**0.77**	**13.39**

V_1 – BRRI dhan29, V_2 – BRRI dhan60, V_3 – BRRI dhan61

T_0= No cadmium applied, T_1= 20 ppm Cd,T_2= 40 ppm Cd, T_3= 60 ppm Cd, T_4= 80 ppm Cd

* Significant at 5% level

Calcium content

Ca content in straw and root varied significantly due to the interaction effect of variety and different cadmium doses and (Table 7). The highest Ca content in straw (0.559%) was observed from V_3T_0, while the lowest result (0.228%) was recorded from V_3T_4 which was statistically similar with V_3T_3 (0.272%). In case of root, the maximum Ca content (0.346%) was observed from V_2T_0 which was statistically similar with V_2T_1 (0.315%), while the minimum result (0.125%) was recorded from V_1T_4 which was statistically similar with V_1T_3 (0.142%) and V_3T_3 (0.154%).

Table 7. Effect of combination of variety and cadmium on calcium content in grain, straw and root

Treatment		**Calcium content (% Ca)**	
		Straw	**Root**
V_1	T_0	0.426 c	0.244 cde
	T_1	0.423 c	0.228 cde
	T_2	0.408 c	0.194 ef
	T_3	0.382 cd	0.142 fg
	T_4	0.315 ef	0.125 g
	T_0	0.479 b	0.346 a

V_2	T_1	0.406 c	0.315 ab
	T_2	0.346 de	0.280 bc
	T_3	0.322 ef	0.262 bcd
	T_4	0.307 ef	0.139 g
V_3	T_0	0.559 a	0.266 bcd
	T_1	0.346 de	0.217 de
	T_2	0.332 de	0.193 ef
	T_3	0.272 fg	0.154 fg
	T_4	0.228 g	0.132 g
LSD $_{(0.05)}$		**0.053**	**0.053**
Significant level		*	*
CV (%)		**2.42**	**3.89**

V_1 – BRRI dhan29, V_2 – BRRI dhan60, V_3 – BRRI dhan61
T_0= No cadmium applied, T_1= 20 ppm Cd,T_2= 40 ppm Cd, T_3= 60 ppm Cd, T_4= 80 ppm Cd
NS – Non Significant* Significant at 5% level

Cadmium content

Cd content in straw and root varied significantly due to the interaction effect of variety and different cadmium doses and (Table 8). The highest Cd content in straw (39.17 mg kg^{-1}) was observed from V_1T_4, while the lowest result (2.980 mg kg^{-1}) was recorded from V_3T_0 which was statistically similar with V_2T_0 (4.083 mg kg^{-1}) and V_1T_0 (4.360 mg kg^{-1}). The maximum Cd content in root (161.1 mg kg^{-1}) was observed from V_1T_4, while the minimum result (4.050 mg kg^{-1}) was recorded from V_1T_4 which was statistically similar with V_2T_0 (5.020 mg kg^{-1}). These decreases might be attributed to its effects on cell division and/or cell expansion, and may be through its effect on DNA and RNA synthesis; consequently, any change in the growth which results from increasing Cd supply must be dependent on the change in the rate of net photosynthesis that reduces the supply of carbohydrates or proteins and consequently decreases the growth of plant. These results are in agreement with Liu *et al.* (2008)[15] and Wilson (1992)[16] stated the yield reductions in mustard plants have been attributed to the direct effect of higher Cd concentrations in plant tissue and not through an indirectly induced deficiency of other nutrients. Also, Skorzynska and Baszynski (1995)[17] who worked on bean plant pointed out that, the application of Cd resulted in reduction of photosynthesis efficiency and transpiration.

Table 8. Combination effect of variety and cadmium on cadmium content in straw and root

Treatment		**Cadmium content (mg kg^{-1})**	
		Straw	**Root**
V_1	T_0	4.360 g	6.927 k
	T_1	23.94 de	44.98 f
	T_2	29.79 c	46.73 f
	T_3	33.55 b	126.7 b
	T_4	39.17 a	161.1 a
V_2	T_0	4.083 g	5.020 kl
	T_1	18.67 f	32.88 i
	T_2	22.50 e	42.06 g
	T_3	25.30 d	56.48 e
	T_4	32.99 b	95.92 c
V_3	T_0	2.980 g	4.050 l
	T_1	26.06 d	25.84 j
	T_2	28.76 c	36.77 h
	T_3	29.72 c	46.54 f
	T_4	31.30 bc	69.77 d
LSD $_{(0.05)}$		**2.647**	**2.716**
Significant level		*	*
CV (%)		**6.72**	**3.04**

V_1 – BRRI dhan29, V_2 – BRRI dhan60, V_3 – BRRI dhan61
T_0= No cadmium applied, T_1= 20 ppm Cd,T_2= 40 ppm Cd, T_3= 60 ppm Cd, T_4= 80 ppm Cd
* Significant at 5% level

IV. Conclusion

Different rice cultivars and cadmium doses had significant effect on growth and nutrients content of Boro rice. Therefore, the present experimental results suggest that almost all the growth characters were significantly decreased by cadmium contamination. BRRI dhan60 and BRRI dhan61 with no cadmium dose has lower cadmium accumulation in straw and root. Cadmium contamination increased the Cd concentration in straw and root but reduced the concentration of K, Na, Ca. Thus, Cd contamination reduced growth and nutritional quality of grains.

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