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OUTCOMES OF CADMIUM POIIUTION ON YIELDAND CADMIUM CONCENTRATION IN DIFFERENT VARIETIES OF RICE

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ABSTRACT

A pot experiment was conducted in the net- house of the Department of Agriculture of Bangabandhu Sheikh Mujibur Rahman Science and Technology University, Gopalgonj to evaluate the outcomes of cadmium pollution on the growth, yield and nutrient concentrations of six varieties of rice. Cadmium(Cd) was added at three rates viz. 0, 10 and 20 ppm (on soil basis) from cadmium chloride ($CdCl_2.H_2O$). The varieties tested were BINA dhan8, BINA dhan10, BINA dhan14, BRRI dhan50, BRRI dhan58 and Kheyali boro. The experiment was carried out in a Completely Randomized Design (CRD), with three replicaions. Nine kg soil was taken into each pot measuring 40 cm in diameter and 35 cm in height. Every pot received 100 ppm N, 25 ppm P, 40 ppm K and 25 ppm S from urea, triple superphosphate, muriate of potash and gypsum, respectively. Soils were treated with Cd as per treatments before transplanting. Cadmium contamination significantly decreased plant height, tillering, panicle length, grains pot^{-1}, 100-seed weight, grain yield and straw yield. However, the effect was quite varied with the rice varieties. The Cd concentration in both grain and straw of all rice varieties increased with increasing rate of Cd addition. BINA dhan8 had the lowest grain Cd concentration and Kheyali boro showed the highest Cd concentration in rice grown with 20 ppm Cd. Application of Cd had reduced the concentrations of N, P, K and S in grain, showing negative interaction between them. The yield of BRRI dhan58 demonstrated the highest yield of grains pot^{-1} followed by BRRI dhan50 and BINA dhan8 under 20 ppm Cd applied to soil.

INTRODUCTION

Cadmium (Cd) is one of the most toxic pollutants in the surface soil layer (Sanita di Toppi & Gabrielli, 1999). Cadmium is a class one carcinogenic element in nature and is non-degradable contaminant which can be transfered from soil to plants (Meharg *et al*., 2013, Satarug *et al*., 2003). Its accretion in crops and soils is an increasing concern to crop production (Hall, 2002). 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 (Angelova *et al.*, 1999). Cadmium is a relatively rare metal with no biological function, and is highly toxic to plants and animals levels of Cd in plants are not toxic to crops but can cause to substantial Cd nutritional intake by humans (Wagner 1993). In the case of "Itai-itai disease", Cd- polluted rice was the major source of Cd intake in the patients (Yamagata and Shigematsu 1970). This is the earliest case of chronic Cd toxicity in general populations without specific industrial exposure. Even in recent general populations in Japan, the internal Cd level is higher than those of other countries and this is largely because of daily consumption of Japanese rice which contains relatively high Cd (Watanabe *et al.,* 1996; Watanabe *et al*. 2000; Tsukahara *et al*. 2003). Cd

concentrations of recent Japanese rice have been continuously higher compared to those of other countries (Watanabe *et al*., 1996; Shimbo *et al*., 2001), although the values are much lower than the limit established by the Codex Alimentarius Commission of FAO/WHO (0.4 mg/kg). In some areas in China and Thailand, production of highly Cd-polluted rice and renal dysfunctions among populations were reported (Nordberg *et al.,* 1997; Jin *et al.,* 2002; Honda *et al.,* 2010).

Increase in international concern about the risks connected with long-term consumption of Cd contaminated crops has led the international food standards organization, Codex Alimentarius Commission, to propose a 0.1 mg Cd kg^{-1} limit for cereals, pulses and legumes (Harris and Taylor, 2001). Plant internal transport of Cd may be influenced by different factors, such as transpiration rate and plant internal chelators (Salt and Rauser, 1995). Earlier it has been reported that the uptake and accumulation rate of Cd changes among plant species (Ozturk *et al*., 2003) and genotypes of a given species (Dunbar *et al*., 2003). Recently Hassan *et al.* (2005a) have observed differences between rice cultivars in their ability to absorb and accumulate Cd in roots and shoots. However, the mechanisms of its uptake and translocation in plants have not yet been sufficiently studied to date. The maximum acceptable intake of Cd for humans, recommended by FAO/WHO is 0.83 μg day^{-1} in body weight (Nakashima *et al.* 1997).

The Cd content in rice must not be more than 0.4 mg kg^{-1} in order to avoid occurrence of renal dysfunction due to Cd toxicity (Nakashima *et al*., 1997).

The present research was undertaken with the following objectives:

1. To assess the effect of cadmium on growth, yield and nutrient composition of ricegenotypes.
2. To select Boro rice variety for lower grain cadmium concentration.

REVIEW OF LITERATURE

Cadmium is among the most widespread and toxic heavy metals in several parts of the world. It is one of the main pollutants in paddy fields near industrial areas and highly toxic to plant growth and development. Several strategies have been proposed for the successful management of the Cd-contamination in crops. In this chapter an attempt has been made to review some of the research findings in Bangladesh and elsewhere related to the effect of Cd on rice.

Sources of cadmium in the environment

McGrath et al. (1987) stated that the uptake of heavy metal by plants depends on their concentration in soils. But these metal ions are not always in available forms for plants. It was reported that once the metals are in the soil they are held by soil particle and there is little removal by plants uptake. The availability of such metals depends on some factors like, pH of soil, organic matter, clay content, cation exchange capacity from other external sources.

OECD (1991) reported that cadmium in soils is derived from both natural and anthropogenic sources. Natural sources include underlying bedrock or transported parent material such as glacial till and alluvium. Anthropogenic input of cadmium to soils occurs by aerial deposition and sewage sludge, manure and phosphate fertiliser application. Cadmium is much less mobile in soils than in air and water. The major factors governing cadmium speciation, adsorption and distribution in soils are pH, soluble organic matter content, hydrous metal oxide content, clay content and type, presence of organic and inorganic legends, and competition from other metal ions.

as dust, subsequently being deposited into fresh water. In addition, notable levels of Cd entered soil as a direct result of agricultural and industrial activities.

Thornton (1992) highlighted that cadmium is only found in very low levels (less than 1 μgL^{-1} in contaminated waters, although soils, on the other hand, are believed to contain up to 5 $mgkg^{-1}$. Such levels increase as a result of human activities, resulting in significant contamination around the world.

WHO (1992a) reported that, thus producing cadmium oxide in the air, reacting with water vapour, carbon dioxide and other gases to produc $CdCO_3$. Such salts are not able to dissolve in water, but, with the passing of time,change form and become water soluble, namely through converting into $Cd(NO_3)_2$ and $CdCl_2$. With this in mind, a number of different human industrial activities are recognized as adding to the environmental contamination of cadmium.

WHO(1992b). Also reported that with the presence of $CdSO_4$ in soil demonstrating that lettuce leaves have Cd levels amounting to 800 $mgkg^{-1}$. Furthermore, Cd contamination is also recognized as stemming from fertilizers.

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Mench et al. (1998) reported that leafy vegetables and potato tubers naturally accumulate higher levels of Cd than do fruits and cereals. Moreover, tillage and crop rotation practices similarly have a greater impact upon the Cd content of food than does the concentration of Cd in soils.

McLaughlin *et al.* (1999) stated that heavy metals are found ubiquitously in both polluted and unpolluted soils. Although these heavy metals occur naturally in the Earth's crust, they tend to be concentrated in agricultural soil because of irrational
application of commercial fertilizers, manures and sewage sludge containing heavy metals and of contamination caused by mining and industry.

Unwin (1999) reported that the metals are deposited in agricultural lands primarily by atmospheric deposition, the use of organic and inorganic fertilizers and the disposal of sewage sludge and other waste materials. Apart from atmospheric deposition, phosphate fertilizers are the major source of cadmium.

Sultana (2000) conducted an experiment on the effect of intensive fertilization heavy metal concentration in soils and plants. She found that Cd, Pb and Zn concentrations

FAO/WHO (2002) reported that the results indicated that LVB rice had acceptable concentrations of Cd, however, rice from Mwanza City paddy fields need attention because the concentration is close to the limit of allowable concentration.

Adriano *et al*. (2005) argue that in general, chloride can be expected to form a soluble complex with Cd^{2+} as $CdCl^{+}$, thereby decreasing the adsorption of Cd^{2+} to soil particles. In contrast to inorganic ligand ions, Cd^{2+} adsorption by kaolinite, a
variable-charge mineral, could be enhanced by the presence of organic matter via the formation of an adsorbed organic layer on the clay surface.

Moradi *et al*. (2005) reported that Cd in soils is derived from both natural and anthropogenic sources. Naturally a very large amount of Cd is released into the environment, about 25,000 t a year. About half of this Cd is released into rivers through weathering of rocks and some Cd is released into the air through forest fires and volcanoes. The main anthropogenic input of Cd to soils occurs by industrial waste from processes. Even domestic sewage sludge, which originated from the strictest control sources, contains Cd and adds it to pollution. From the sewage

systems, Cd enters into rivers and streams. The addition of Cd in metal rich sewage sludge may also result in contamination of groundwater.

Simmons *et al*. (2005) mentioned that the mean value of Cd concentrations in soil samples for weight with the average of 0.64 mg Cdkg^{-1} dry weight, which was 3.5 times of the Thai standard safety limit of 0.15 mg Cdkg^{-1} dry weight. It indicated that a soil sample from Mae Sot district is a Cd-contaminated soil. So, rice grains are always exposed to the threat of Cd contamination because of high levels of Cd in the soil.

Bhattacharya et al. (2006) highlighted those anthropogenic activities, such as mining and smelting of ores have increased the occurrence of heavy metal contamination of soil and water sources.

Mico *et al*. (2007) observed that total concentrations of heavy metals in the LVB paddy soils were generally similar to values in agricultural soils in the Mediterranean region.

Liu *et al*. (2007) mentioned that by the early 1990s, the worldwide annual release of Cd reached 22,000 tons, which was mostly distributed in the water and soil.

SCHER (2006) reported that phosphate rocks of igneous origin normally contain less than 15 mg Cdkg^{-1} P_2O_5 (phosphate fertilizer) compared with 20 to 245 mg Cd in sedimentary counterparts. Therefore, European fertilizer producers had put forward a limit of 60 mg Cdkg^{-1} for importing phosphate fertilizers by the year 2005 and the Czech Republic has notified the European Commission it wishes to maintain its precession upper limit of 50 mg Cdkg^{-1} P_2O_5 for phosphate fertilizers in 2005.

Williams *et al.* (2009) reported that areas of agricultural soils contaminated by Cd have been widely increasing in many countries as a result of anthropogenic activities, such as disposal of industrial effluent, mining waste, and sewage sludge, and application of phosphate fertilizers. **C**admium sources to paddy soils can be primarily natural (Bandara *et al*. 2008), from base mining contamination (Sriprachote *et al*. 2012, Honda *et al.* 2010, Williams *et al.* 2009), industrial discharge (Horiguchi, 2012), or from phosphate fertilizers (Morwedt & Osborn, 1982).

Haynes et al. (2009) reported that in most developing countries, biosolids are still major source of heavy metal input to soils.

Li *et al.* (2009) reported that the mean Cd concentration in the 0–20cm soil layer in Zhangshi irrigation area (ceased in 1992) is still 1.75 mg/kg and the highest Cd value is up to 10 mg/kg in some sampling points.

Naser *et al*. (2012) determined the levels of lead, cadmium and nickel in roadside soils and vegetables along a major highway in Gazipur, Bangladesh were investigated. Soil samples were collected at distances of 0, 50, 100, and 1000 m (meter) from the road. The concentrations of Pb and Ni in soil and vegetables (bottle gourd and pumpkin) decreased with distance from the road, indicating their relation to traffic and automotive emissions. The concentration of Cd was found to be independent of distance from road.

Yi-Chu Chang *et al*. (2012) conducted an experiment and found that the changes in Fe concentration in Cd-treated rice (*Oryza sativa* L.) seedlings. Exogenous addition of excess Fe-citrate decreased Cd concentration and Cd toxicity of rice seedlings. This study suggests that the improvement of Fe status is able to reduce toxicity of rice seedlings to $CdCl_2$.

Meharg et al. (2013) found from a survey conducted in 12 countries of four continents that cadmium level in rice grain were the highest in Bangladesh and Sri Lanka where the per capita rice intakes is also high. In Bangladesh, the minimum, maximum and average concentration of Cd in rice was 0.0005, 1.31 and 0.099 mg kg^{-1}, respectively.

Cadmium availability to plants

Riffaldi et al. (1983) obtained significant correlations between Cd sorption and phenolic hydroxyl groups and carboxyl groups of fulvic acids.

Lu *et al*., (1992) reported that under low Eh in soil, H_2S is produced in Mae Sot district, Tak province ranged from 0.5-0.8 mg $Cdkg^{-1}$ dry and than Cd reacts with S^{-2} forming insoluble CdS; thus Cd is not easily absorbed by crops.

Del Castilho et al. (1993) observed that low-molecular fractions, such as hydrophilic bases, have a strong affinity to form soluble Cd complexes.

Naidu et al. (1994) found that three possible reasons have been advanced for this phenomenon First, in variable-charge soils, a decrease in pH causes a decrease in surface negative charge, lowering cation adsorption. Second, a decrease in soil pH is likely to decrease hydroxy species of metal cations, which are adsorbed preferentially over mere metal cations. And third, acidification causes th dissolution of metal compounds, increasing the concentration of metals in soil solution.

Hernandez *et al*., (1996) mentioned that mean while, the presence of plentiful Fe^{3+} and Mn^{4+} is competitive with Cd^{2+} thereby reducing plant absorption. For instance, Cd absorption and accumulation was significantly reduced with diminishing Eh in reductive conditions formed by flooding rice field.

Li *et al.,* (1997) reported that Cd also reduced the absorption of nitrate and its transport from roots to shoots, by inhibiting nitrate reductase activity in the shoots indicating the potential possibility of reducing grain Cd accumulation by means of genetic improvement. Breeding for low Cd accumulating cultivars has been undertaken in sunflower and durum wheat .

Das *et al*. (1997) reported that uptake, transport, and subsequent distribution of nutrient elements by the plants can be affected by the presence of Cd ions. In general, Cd has been shown to interfere with the uptake, transport, and use of several elements (Ca, Mg, P, and K) by plants.

Sauve et al. (2000) investigated that in soils containing large amounts of OM, such as pasture soils and organic manure-amended soils, only a small proportion of the Cd in soil solution remains as free Cd^{2+} and a large portion is complexed with soluble organic carbon Addition of manure and composted biosolids has been found to increase the complexation of Cd in soils, the extent of which is related to the amountof DOC.

Bakhtiarian *et al.* (2001) reported that the effect of the Kor river's pollution on the Pb and Cd content of the Korbal rice samples. A study on the comparison of the pollution level of the Korbal and Gilan rice samples showed that the lead and Cd content of the hybrid, prolific and late rice sample types were greater than that of Matusik *et al.* (2008) reported that several plant nutrients have many direct as well as indirect effects on Cd availability and toxicity. Direct effects include decreased Cd solubility in soil by favoring precipitation and adsorption.

Romkens *et al.* (2009) reported that irrespective of rice cultivars, the combination of elevated total Cd concentrations in soil, a low pH, and low soil OM content results in an increased availability of Cd in soil, this result in a high uptake of Cd by rice plants.

Li *et al.* (2009) investigated the effects of pig manure on the distribution and accumulation of Cd in a soil–rice system using a pot experiment. Results showed that application of pig manure decreased the concentrations of Cd in rice roots by 35.6%. They observed that pig manure not only decreased uptake of Cd by rice but

also restrained the transfer of Cd from the rice root to the stem and grain. The application of amendments increased soil pH and resulted in the reduction of Cd concentrations in soil solutions, which were significantly correlated to the uptake of Cd by the rice stem and grain.

2.3. Effects of Cd on plants

Herawati *et al*. (2000) mentioned that Cd concentration above 20 μgg^{-1} in soil reduces rice plant biomass by poisoning the roots and restricting growth.

Ivano (2001) observed that heavy metals are toxic to higher plants by causing oxidative stress, displacing other essential metals in plant pigments or enzymes, leading to disruption of function of these molecules and of many metabolicprocesses, and finally reducing growth and yield.

Wang et al. (2001) investigated Cd levels in soils and rice or wheat in contaminated

areas throughout 15 provinces of China. The results indicated that the levels of Cd, Hg and Pb in some crops were greater than the Governmental standards. Cadmium level in rice was 7 mg kg^{-1} in the wide area of the country. For rice and wheat, the latter seemed to have much higher concentrations of Cd and Pb than the former grown in the same area. For examples, 6.9 mg $Pbkg^{-1}$ was in cortex of wheat compared to 0.65 $mgkg^{-1}$ in the same parts of rice.

Hu and Kao (2003) observed that in second leaves of rice plants decreased in chlorophyll content of cv. Tainung 67 (TNG 67) was less than cv. Taichung Native-1 after Cd treatment, while the decrease in photosynthetic rate a Zhou *et al.* (2003) found that rice plant height and grain yield were decreased by about 4 to 5 cm and 20 to 30%, respectively due to the effect of Cd concentrations in rice plants.

Zhou *et al.* (2003) found that percolation pattern is one of the important factors together with soil pH, temperature, anaerobic bacteria, heavy metal concentration, gravel size and soil fertility for the growth and development of rice plants. Percolation pattern controls the oxidation-reduction status of soil, consequently the

uptake of Cd by rice plants. A closed system percolation pattern can be considered a tool to reduce Cd uptake by rice plants, growing in Cd polluted paddy fields.

Kyuma (2004) mentioned that flooding of paddy fields is effective in reducing grain levels of Cd.

Chamon *et al. (2005)* conducted pot and field studies including with the contaminated soils to see heavy metal accumulation in rice and wheat at harvest. They observed that wheat varieties accumulated significant amount of different heavy metals.

Cheng *et al.* (2005) reported that Cd stress significantly reduced grain yield and panicle number plant^{-1}, spikelets panicle^{-1}, filled spikelet rate and grain weight, and shoot dry weight at various growth stages

in grain by means of water management alone. Silicon fertilization decreases Cd concentrations in rice grain.

Zhang and Ge (2008) reported that an increase of glutathione-S-transferases (GST) activity was found in rice shoots, while in roots the activity of the enzyme was inhibited by Cd treatments. Compared with shoots, rice roots had higher GST activity, indicating that the ability of Cd detoxification was much higher in roots than in shoots.

Seth *et al.* (2008) added that, damage to the DNA in root-cap cells has been found in rice.

Zhu *et al.* (2008) observed that in China, large areas of agricultural soils and many tons of crops such as rice (*Oryza sativa* L.) have been highly polluted by Cd in some provinces, including Hunan.

Zeng *et al.* (2008) reported that in a slightly contaminated soil (1.09 mg Cdkg^{-1} soil), the absolute difference in grain Cd concentrations among 138 rice cultivars was 9.1 fold.

Arao *et al.* (2009) reported that once the field is drained, the soil becomes an oxidative condition and CdS in the soil is changed to Cd^{2+} which is much available to plants. This flooding water management before and after heading drastically reduces grain Cd concentrations, but on the contrary, this treatment
increases As concentration in grains.

Williams *et al.* (2009) found that 65% of the field rice in Hunan province of China exceeded the national food standard for Cd.
Hassan *et al*. (2005) also found that the toxic effect of Cd on rice varied with the form of nitrogen fertilizer, and application of $(NH_4)_2SO_4$ to Cd stressed rice plants, compared to NH_4NO_3 or Ca

$(NO3)_2$, would be beneficial to mitigate detrimental effect of Cd and to reduce Cd accumulation in plants.

nd Popova *et al.* (2009) found that Cd also produces alterations in the functionality of membranes by inducing changes in their lipid and fatty acid composition.

Farooqi *et al.* (2009) and Shafi *et al.* (2010) reported that germination and growth of plants can be adversely affected by Cd.

Lee *et al.* (2010) and Rodriguez-Celma *et al.* (2010) reported that Cd affected the synthesis of 36 proteins in rice. In roots, the synthesis of 16 proteins was increased, while the synthesis of 1 protein was reduced. In leaves, the synthesis of 16 proteins
was up-regulated, while the synthesis of 3 proteins was down-regulated. Treatment of tomato plants with a low Cd concentration (10 μM) induced changes in 36 polypeptides, while higher Cd concentration (100 μM) induced changes in 41 polypeptides.

Rodda (2011) suggested the timing of Cd accumulation in rice plants and determined the major period for accumulation of Cd which can be translocated to the grain. Cadmium was supplied to the roots of rice plants grown under static hydroponic conditions at a non-toxic, environmentally relevant concentration (50 nM), according to three different timing regimes: (1) pre-flowering Cd, (2) post- flowering Cd, or (3) continuous Cd. The rate of accumulation of Cd in the developing grain was monitored by harvesting immature rice panicles at four time points prior to a final harvest. It was estimated that 60% of the final grain Cd content was remobilized from that accumulated by the plant prior to flowering and the other 40% came from uptake during grain maturation. This study showed that Cd uptake from the root to the grain in rice is indeed possible in post-flowering and it is an important source of grain Cd.

Yadav (2010) and Rascio & Navari-Izzo (2011) reported that effect of Cd on growth and development Cd toxicity causes inhibition and abnormalities of general growth in many plant species. After long-term exposure to Cd, roots are
chlorophyll content due to Cd toxicity is genotypic dependent.

MATERIALS AND METHODS

In this chapter a brief description of location, climate, soil, crop, experimental design, treatments, cultural operations, collection of soil and plant sample and the methods followed for chemical analysis are statistical analysis and presented in this chapter.

Pot Experiment

The pot experiment was carried out during the boro season of 2019 to evaluate the effect of cadmium on boro rice genotypes.

Description of the Experimental Site

Location

The growth and performance was carried out in the net house of the Department of Agriculture, Bangabandhu Sheikh Mujibur Rahman Science and Technology University, Gopalgonj. The net house belongs to the same environment of BSMRSTU farm (AEZ 7).

Climate

It has sub-tropical humid climate and is characterized by high temperature accompanied by moderately high rainfall during kharif season (April-September) and low temperature in rabi season (October-March). Geographically, the net house stands at 24.75ºN latitude and 90.50ºE longitude at the height of 18 m above themean sea level.

Collection and preparation of soil

A bulk volume of soil was collected at a depth of 0-l5 cm from the of the Department of Agriculture, Bangabandhu Sheikh Mujibur Rahman Science and Technology University, Gopalgonj. After collection, the soils were made free from the plant roots and unnecessary materials and dried under sunlight for 2 weeks. Thenthe soil sieved and mixed up thoroughly and ready for potting.

Pot preparation

An amount of 9 kg soil was taken in a series of pots. Each plastic pot was 0.23 $m^{2.}$ There were altogether 54 pots comprising 3 different treatments to six different boro rice varieties with 3 replications. Water was added to the pot to bring the soil up to saturation.

Treatments of the experiment

Three rates of cadmium *viz.* 0, 10 and 20 ppm Cd (on soil weight basis) were applied on six boro rice varieties. The source of Cd was $CdCl_2.H_20$. The rice varieties were *viz*, V_1=BINA dhan8, V_2= BINA dhan10, V_3= BINA dhan14, V_4=BRRI dhan50, V_5=BRRI dhan58 and V_6=Kheyali boro. Treatment consisted of three concentrations of cadmium. The experiment was carried out in a completely randomized block design. Each pot contained one hill of 3 seedlings.

Description of rice cultivars under study

BINA dhan8

BINA dhan8 was developed by the scientists of BINA (Bangladesh Institute of Nuclear Agriculture) and was officially released by National Seed Board of Bangladesh in 2010. It is a salt tolerant variety which can survive up to 10 dSm^{-1} salinity. Its crop duration is 135-145 days and average yield is 3-6 t ha^{-1} depending on the levels of salinity.

BINA dhan10

BINA dhan10 was developed by the scientists of BINA (Bangladesh Institute of Nuclear Agriculture) and was officially released by National Seed Board of Bangladesh in 2013. It is a salt tolerant variety. Its crop duration is 115-125 days and average yield is 4.50-5.50 t ha^{-1}.

BINA dhan14

BINA dhan14 was developed by the scientists of BINA (Bangladesh Institute of Nuclear Agriculture) and was officially released by National Seed Board of Bangladesh in 2013. It is a high yielding variety. Its crop duration is 120-130 days and average yield is 7 - 7.66 t ha^{-1}.

BRRI dhan50

BRRI dhan50 was developed by the scientists of BRRI (Bangladesh Rice Research Institute). It is a boro rice and aromatic fine rice better than Basmoty in quality. It is resistant to water logging condition. BRRI dhan50 requires 155 days to mature and average yield is 6 t ha^{-1}.

BRRI dhan58

BRRI dhan58 was developed by the scientist of BRRI (Bangladesh Rice Research Institute) and it was officially released by National Seed Board of Bangladesh in 2012. It is a boro rice variety. BRRI dhan50 requires 150-155 days to mature and average yield is 7-7.5 t ha^{-1}.

Kheyali boro

It is a local variety grown in low lying areas of Islampur upazila.

Fertilizer application

All the pot received 100 ppm N, 25 ppm P, 40 ppm K and 25 ppm S from urea, triple super phosphate, muriate of potash and gypsum, respectively. The amounts of nitrogen, phosphorus, potassium and sulphur required for each pot were calculated as per their rates of application. Except nitrogen, full dose of P, K were added at the

time of final pot preparation. Nitrogen was added in three equal splits at 7, 30 and 45 days after transplanting (DAT). Cadmium was added to soil before transplanting.

Transplanting of seedlings

The seedlings were uprooted carefully from the seedbed in the morning and transplanted in the same day. Three healthy seedlings of forty days age were transplanted in the pots on 30 January 2014.

Intercultural operations

Weeding and loosening of soils around the hills were done when felt necessary. Top dressing of urea was done when felt necessary. At the grain filling stage, the pots were covered with net to protect the grains from the attack of birds. Observation was regularly made. All the stages of plants and plants response as per treatments were observed carefully.

Irrigation

Six cm water was added after transplanting and maintained for 15 days after transplanting. Then water was added following saturation system and allowed to dry until where hair cracking was observed. This process was continued up to panicle initiation stage.

Harvesting

The crop was harvested at full maturity on 19 May 2019. Plants of each pot was bundled separately with tag mark indicating the respective treatment combinations and brought to the laboratory for recording data on yield and yield parameters.

Sampling threshing and processing

The plant samples were dried in an oven at 60 ^{0}C for 48 hours and then cut into small pieces using clean scissors. The plant materials were stored in desiccators to analyze total N, P, K, S and Cd concentrations.

Data Collection

The following data were collected from all the plants grown in each pot.

Plant height

The height of the plant (cm) was measured from the ground level to the top of the flag leaf at 30, 45, 60 days after transplanting (DAT) and harvest with help of scale.

Effective tillers pot^{-1}

Number of effective tillers per hill^{-1} was counted at 30, 45, 60 days aftertransplantation (DAT) and at harvest.

Panicle length

Panicle length was measured in cm from basal node of the rachis to apex.

Filled grains pot^{-1}

The number of filled grains was counted for each panicle.

100-grain weight

Hundred grains were taken from each pot and the sun dry weight was measuredusing an electrical balance.

Grain yield

Grain obtained from each pot was dried and weighed carefully. The yields wereexpressed as g pot^{-1} on 14% moisture basis.

RESULTS

Results obtained from the pot experiment conducted in the net house of the Department of Agriculture, Bangabandhu Sheikh Mujibur Rahman Science and Technology University, Gopalgonj.have been presented in tables and graphs and narrated in this chapter under following headings:

Plant height

Plant height of rice varieties adversely affected due to application of different rates of cadmium to soil (Table 4.1). Plant height of 88.9 cm was found in the pot without any Cd treatment and the treatment 10 and 20 ppm Cd recorded the plant height of
85.2 cm and 82.2 cm, respectively. A significant variation in plant height was also observed among different varieties of rice (Table 4.1). The Kheyali boro was the tallest one (99.2 cm) and the shortest variety was BINA dhan14 (74.7cm). The plant height of Kheyali boro was statistically significant over all other varieties. The second tallest plant (93.4cm) variety was BINA dhan10. The shortest plant of 84.5 cm was statistically similar to BINA dhan8. The varieties BINA dhan4 and BRRI dhan 50 were also

dhan58 were less affected by 10 ppm Cd application. The application of 20 ppm Cd drastically reduced the plant height compared to those without any Cd application Panicle length

Cadmium contaminaiton of soil significantly decreased the panicle length of rice varieties (Table 4.1). The panicle length of rice varieties significantly decreased due to 10 ppm Cd application and further significantly decreased with the addition of 20 ppm Cd. There was significant variation among the different varieties of boro rice (Table 4.1). The panicle length was in the range of 19.5 cm in Kheyali boro to 25.4 cm in BINA dhan10.

The interaction effect of different treatments with varieties showed remarkable variations in panicle length of rice though the variation was not statistically significant (Table 4.2).

DISCUSSION

A study was undertaken during the Boro season of 2019 to evaluate the effect of Cd on boro rice genotypes. The experiment was conducted in the net house of the Department of Agriculture, Bangabandhu Sheikh Mujibur Rahman Science and Technology University, Gopalgonj.Soil application of Cd showed distinct negative effect on the growth and yield of Boro rice cv. BINA dhan8, BINA dhan10, BINA dhan14, BRRI dhan50, BRRI dhan58 and Kheyali boro. All the growth parameters tested in the experiment viz. plant height, panicle length, grains pot^{-1} and 100-grain weight were affected by the application of Cd. Cadmium has been marked as poisonous heavy metal both for plants and animals (Holmgren *et al*., 1993; Das *et al*., (1997). The addition of Cd to the crops decreased the growth, yield and yield contributing characters. There are many reports that application of Cd can affect crop growth and yield. According to Sarkunan *et al.,* (1991), rice yield drastically decreased due to the application of 20 ppm Cd. Similar results were reported by Alloway (1988) and Dixit (1992). Cadmium concentration above 20 ppm in soil reduces rice plant biomass by poisoning the roots and restricting the growth (Herawati *et al.,* 2000). According to Cheng-wang *et al*., (2005) Cd stress significantly reduced grain yield and panicle length, number of spikelets panicle^{-1} and filled grain and grain weight and shoot dry weight at various growth stages. The toxic effect exerted by the Cd in plants was the reasons for getting negative effects of Cd.

Grain and straw yields of Boro rice were also found to be affected by As and Cd application in soil. Liu-Jian Ghou *et al.* (2007) found that only a very small portion (0.73%) of Cd absorbed by rice plant was transferred to grain. Cd concentration in rice grain was governed somewhat by plant Cd uptake and the transport of Cd from root to shoot and in a greater extent, by the transport of Cd from shoot to grain. Arao *et al*. (2010) reported grain and straw Cd concentrations 0.4 and 2.0 mg kg^{-1} respectively. Therefore, further experimentation is needed to validate the results reported here.

This finding also supports the negative effects of Cd on crops. Adverse effects of heavy metals on crops have been reported by Singh and Nayyar (1991) and Sarkunan *et al*., (1991). Cadmium contamination in rice decreased the nutrient element (N, P, K and S)) concentration both in grains and straw.

The concentration of Cd in rice grain was higher in Cd treated pot than the value in Cd untreated pots. The concentration of Cd increased progressively with increasing levels of Cd application. Cadmium is readily available and labile element therefore if present or accumulated in soils, would be taken up by plants and ultimately increased the concentration of Cd in plant parts. Addition of Cd can increase its content in grain and straw of rice (Sarkunan *et al.,* 1991). It was found that Cd content in KMD rice grains reached 0.68, 0.68 and 1.45 mg kg^{-1} respectively at the Cd rates of 5, 10 and 20 mg kg^{-1} soil (Haiyan *et al*., 2009).

CONCLUSION

The following conclusions may be drawn from the results of the experiment on “effects of cadmium contamination on yield and cadmium concentration in different varieties of boro rice”.

Cadmium contamination significantly reduced the effective tillers, plant height, seeds panicle^{-1}, 100-seed weight, grain and straw yield of all rice varieties.

BRRI dhan58 had the highest yield of grains pot^{-1} followed by BRRI dhan50 and BINA dhan8 under 20 ppm Cd applied to soil.

Cadmium contamination increased the Cd concentration in grain but reduced the concentration of N, P, K and S. Thus Cd contamination reduced grain yield and nutritional quality (N, P, K and S) of grains.

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