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Effects of lime and organic manure on cadmium content in soil and maize crop

MA. Ullah[1], MR. Islam-1[2], MMH. Sarker[3], M. Mehnaz[1], HAK. Chowdhury[1], S. Karmaker[1], SM. Shamsuzzaman[*1]

[1]*Soil Resource Development Institute, Krishi Khamar Sarak, Dhaka, Bangladesh*

[2]*Department of Soil Science, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh, Bangladesh*

[3]*Department of Soil Science, Faculty of Agriculture, Sylhet Agricultural University, Sylhet, Bangladesh*

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Abstract

Toxic heavy metals like cadmium (Cd) contaminated industrial wastes and effluents are being discharged directly to soils. Moreover, non-judicious use of chemical fertilizers especially phosphate have aggravated the Cd level of soil. Thus, the polluted soils need to be amended for crop production. With this idea in mind, pot experiment was conducted at Bangladesh Agricultural University (BAU) net-house to examine the effect of lime and organic amendments on yield and Cd concentrations in maize grown in polluted soils. There were four treatments: no soil amendment (Control), Lime 10g pot^{-1}, cow dung (CD) 80g pot^{-1} and poultry manure (PM) 80g pot^{-1}. The addition of lime and organic matter (CD and PM) significantly increased the grain and stover yields of maize. Application of lime and organic manure to the soils reduced Cd concentration in the plant under study as compared with control. Overall, the addition of lime and organic manure to the soils increased the maize yields and reduced the Cd concentration in the plant as well as decrease the heavy metal phytoavailability under study as compared with control.

* **Corresponding Author:** SM. Shamsuzzaman ✉ shamsuzzamansm@gmail.com

Introduction

Cadmium (Cd) has been identified as one of the most common toxic heavy metals for plants and animals. It is also known as one of the major environmental pollutants. This toxic heavy metal if present or accumulated in soils would be taken up by plants and ultimately enters into the food chain (Hong *et al.*, 2008; Loganathan *et al.*, 2012). Arable soils in many areas of the world are moderately contaminated with Cd (Kukuchi *et al.*, 2007). This moderate Cd contamination in soils leads to a considerable accumulation of Cd in edible parts of crops (Arao and Ae, 2003; Arao *et al.*, 2003). Such levels of Cd are not toxic to plants but can contribute to substantial Cd dietary intake by humans (Uraguchi and Fujiwara, 2012). Grain products generally have moderate Cd concentrations, but are consumed in relatively large amounts and therefore contribute a substantial amount of Cd to the diet (Yost *et al.*, 1980).

Exposure of Cd can occur through different routes such as water and food. Although many recent studies have determined Cd in foods especially vegetables (Naser *et al.*, 2009; Khan *et al.*, 2010) and rice (Meharg *et al.*, 2013), the number of studies focusing Bangladesh is limited. Cadmium exerts its toxic effects mainly on the kidney. It has been reported that over 20 million people in Bangladesh suffer from kidney disease, especially chronic kidney disease (UNB, 2011). It is a common belief that higher Cd intake through food chain is one of the major reasons for such a high number of kidney patients.

Many scientists are currently trying to effectively remediate the soils contaminated with Cd. The immobilization, which transforms Cd into less bioavailable forms, was considered as one of the most effective ways to remediate the Cd contaminated soils (Ok *et al.*, 2010a, b; Ok *et al.*, 2011). Among immobilizing agents, organic amendments have been shown to effectively alleviate Cd toxicity to plants by transforming the metals into less available fractions (Tandy *et al.*, 2009). Metal absorption by plants is pH dependent and liming is a useful way of reducing the toxicity of Cd (Dinesh-Mani *et al.*, 2007).

In Bangladesh, Poultry Industry is a raising industry for protein supply. It is also important for a huge amount of poultry litter which is also important for organic matter. On the other hand, CD is the traditional source of organic matter. The incorporation of organic amendments (CD, PM etc) into the heavy metal contaminated soils could maintain soil organic matter, improve soil physicochemical properties, and increase plant production (Kim *et al.*, 2010). Moreover, many previous studies have demonstrated the benefits of utilizing organic amendments for immobilization of heavy metals in the soils (Tandy *et al.*, 2009). Therefore, the aim of the present study was to assess the effects of lime and organic amendments on yield and Cd concentrations in maize grown in Cd contaminated soils.

Materials and methods

On the basis of initial Cd status, two soils were selected for conducting the pot experiment at the net house of the Department of Soil Science, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh. One was industrially polluted soil collected from Tongi, Gazipur. Another one was intensively fertilized soil collected from Bangladesh Agricultural Development Corporation (BADC) farm, Feni. Collected initial and post-harvest soils (from each pot) were cleaned, dried and preserved for analyzing soil pH, organic matter, total N, exchangeable K, Ca, Mg, available P, S and total Cd. Soil pH was determined by glass-electrode pH meter maintaining 1: 2.5 soil-water ratio (Page *et al.*, 1982), textural analysis of soil was done by Hydrometer method (Black, 1965) and the textural class was determined by fitting the values for % sand, % silt and % clay to the Marshall's triangular co-ordinate following USDA system. Cation Exchange Capacity (CEC) was determined by sodium saturation method (Rhoades, 1982). Organic carbon was estimated by wet digestion method (Nelson and Sommers, 1982). Total N of soil was determined by Micro-Kjeldahl method (Bremner and Mulvaney, 1982). Available P was extracted from the soil by two different extractant. Acid soils ($pH < 7.0$) were extracted with dilute acid fluoride (Bray and Kurtz's, 1945) and soils having pH greater than 7.0 were extracted with 0.5M $NaHCO_3$ solution (Olsen and Sommers, 1982). Available Zn, Cu, Mn & Fe Extracted by 0.05M DTPA solution (pH 7.3) maintaining 1:2 soil-extractant ratio and directly measured by AAS (Lindsay and Norvell, 1978). Exchangeable Ca, Mg & K Extracted by 1M CH_3COONH_4 maintaining 1:10 soil-extractant ratio and determined by AAS for Ca, Mg and K by flame photometer (Peterson, 2002). To determine EC used digital Electric conductivity meter (Ghosh *et al.*, 1983) maintaining 1:1 soil-water ratio. Extracted by 500 ppm P solution form $Ca(H_2PO_4)_2$, H_2O and estimated by turbidity method using $BaCl_2$ (Fox *et al.*, 1964). To determine total Cd soil sample was digested with HNO_3–$HClO_4$ (4:1) for 1.5 hours at 190° C and determined by atomic absorption spectrophotometer, Model UNICAM 969, England (Yoshida *et al.*, 1976). Physico-chemical properties of the soils are presented in Table 1.

Table 1. Some physical and chemical characteristics of the selected Kalma and Sonatola soil

Characteristics	Kalma series soil	Sonatola series soil
Sand (%)	24.64	25.28
Silt (%)	36.00	56.39
Clay (%)	39.36	18.33
Texture	Clay loam	Silt loam
pH	5.48	6.75
OM (%)	2.24	2.05
Exchangeable Ca (cmol kg^{-1})	7.21	2.65
Exchangeable Mg (cmol kg^{-1})	2.12	1.28
Exchangeable K (cmol kg^{-1})	0.41	0.33
Total N (%)	0.14	0.13
Available P (mg kg^{-1})	15.24	12.54
Available S (mg kg^{-1})	17.25	18.43
Available Zn (mg kg^{-1})	2.14	2.48
Available Mn (mg kg^{-1})	39	28
Available Fe (mg kg^{-1})	141	65
Available Cu (mg kg^{-1})	7.68	0.85
CEC (cmol kg^{-1})	13.15	11.58
Total Cd (mg kg^{-1})	3.87	2.23

There treatments of this experiment were T_1 = No amendment (Control), T_2 = Lime 10g pot^{-1}, T_3 = CD 80g pot^{-1} and T_4 = PM 80g pot^{-1}. Treatments were arranged in a complete randomized design (CRD) with three replications. Ten kilogram of soil (dry weight basis) was taken in a series of non-porous and plastic pots. Each pot was 30 cm in diameter and 32 cm in height. A blanket dose of 345 mg kg^{-1} N, 75 mg kg^{-1} P, 150 mg kg^{-1} K and 30 mg kg^{-1} S was applied to each pot. Urea, triple superphosphate, muriate of potash and gypsum were used as sources of N, P, K and S, respectively. Full doses of P, K, S and Cd (treatment wise), and 1/3rd dose of N were mixed with soil. Nitrogen fertilizer was broadcasted in three equal splits for rice and maize; 1/3 after 7 days of seed sowing, 1/3 after 20 days of seed sowing and rest 1/3 after 45 days of seed sowing. Cow dung and poultry manure were added uniformly into various pots according to the treatments. The soil was submerged with distilled water for 24 hour. Maize seed was sown in December. An equal amount of tap water was added to each plastic pot, whenever required. Intercultural operations were done as and when required. Insects and diseases were controlled as and when required. The crop was harvested at maturity and yield of grain and stover were recorded.

Grain and stover were also collected, dried, ground and preserved in polythene packet for chemical analysis. The samples were digested with di-acid mixture (HNO_3:$HClO_4$ = 4:1). The Cd concentration in the acid digest was determined directly by atomic absorption spectrophotometer (Yoshida *et al.*, 1976).

The data were analyzed statistically by F-test to examine whether the treatment effects were significant (Gomez and Gomez, 1984). The mean comparisons of the treatments were evaluated by DMRT (Duncan's Multiple Range Test). Analysis of variance (ANOVA) for different parameters was done by software package by MSTAT-C program.

Results and discussion

Results of grain and stover yields of maize in amended soil by lime, CD and PM are presented in Fig. 1 & 2. It was observed that the addition of lime, CD and PM significantly increased the grain and stover yields of maize in both soils and in both years. Between two years yields were higher in 2nd year than 1st year. The yields were also higher in Sonatola series soil than Kalma soil series. The highest grain (51.42 and 65.52 $gpot^{-1}$) and stover (55.39 and 69.42 $gpot^{-1}$)

yields were obtained when the contaminated soils were amended with PM in 1st and 2nd year, respectively. The yields were statistically similar when the soil was amended with CD and PM, but lower when the soil was amended with lime. The yields of maize with all amendments were higher to control (not amended) in both soils series.

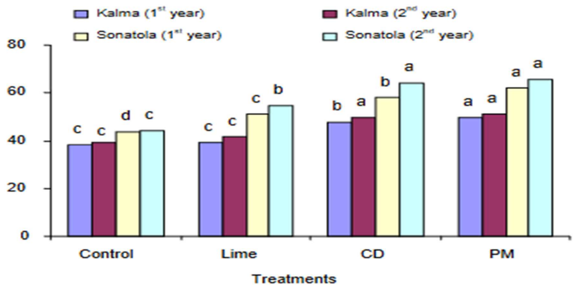

Fig. 1. Effects of lime, CD and PM as a soil amendment on grain yield (consecutive 2 years) of maize

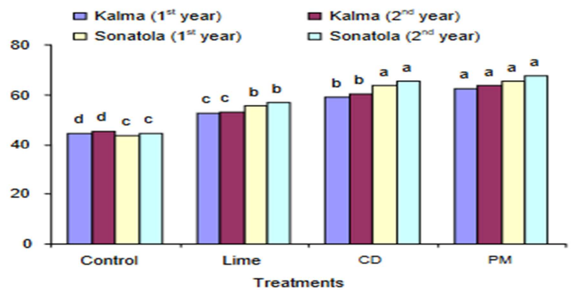

Fig. 2. Effects of lime, CD and PM as a soil amendment on stover yield (consecutive 2 years) of maize in Cd untreated polluted soils

Amendment of polluted soils with lime and organic manures improve the soil physical and chemical properties of soil and thus it increases the yields and quality of crops. Poultry manure possesses more organic matter which adsorbed more Cd. The addition of organic manure (CD & PM) significantly increased the stover yields of maize in both soils. Addition of organic manure could alleviate the Cd toxicity in plants by redistributing them to less available fractions (Azeez *et al.*, 2008). Thus organic matter plays an important role in increasing crop yields through decreasing Cd toxicity. The addition of lime also significantly increased the yields in both the soils. Liming generally decrease the acidity and increase the Ca^{2+} in soil. There are reports that the availability of Cd decreases as the soil pH increases. Moreover, the Ca^{2+} added through liming competes with Cd^{2+} for sorption sites, in addition to this Ca^{2+} will also reduce the surface negative charge density of soil colloid particles, thereby influencing the bioavailability of Cd (Naidu *et al.*, 1997). These reasons might be responsible for the obtained increase in yields due to liming. XiaoFang *et al.* (2011) found that the addition of lime significantly increased the maize grain yields compared with the control.

Cadmium content

Application of lime and organic manure (CD and PM) to soils reduced Cd concentration in the plant under study as compared with control in both soil series (Table 2 & 3). The Cd concentrations of maize grain were found 0.15-0.25 $\mu g g^{-1}$ and 0.14-0.22 $\mu g g^{-1}$ in Kalma and Sonatola soils, respectively. In case of stover Cd, the concentrations were 3.68-5.85 $\mu g g^{-1}$ and 3.44-5.68 $\mu g g^{-1}$ for two soils in different years, respectively. The concentration of Cd in maize grain or stover was lower in PM amendment soils than in CD and lime amendment soils. Such variation indicates a variation of Cd retention capacity of those three materials and also their availability for plant uptake.

The concentration of Cd in grain and stover decreased due to lime, cowdung and poultry manure application over the control treatments because, soil amendment materials act as an immobilizing agent, therefore amended soil contained lower amount of available Cd. Among immobilizing agents, organic amendments have been shown to effectively alleviate Cd toxicity to plants by transforming the metals into less available fractions (Yassen *et al.*, 2007). Several studies have reported that organic matter may reduce Cd availability and mobility via the redistribution of Cd from the soluble or exchangeable form to fractions associated with organic matter, carbonates, Fe/Mn oxides or the residual fractions (HanSong *et al.*, 2010).

Table 2. Effects of Lime, CD and PM as a soil amendment on cadmium content in grain (μg g-1)

Treatment	Kalma		Sonatola	
	1st year	2nd year	1st year	2nd year
T_1	0.25a	0.23a	0.22a	0.20a
T_2	0.21b	0.19b	0.18b	0.17b
T_3	0.19c	0.17c	0.18b	0.16bc
T_4	0.17d	0.15d	0.16c	0.14c
CV (%)	2.15	3.55	1.83	2.24
SE (±)	0.14	0.17	0.10	0.07

T_1 = No amendment (Control), T_2 = Lime 10g pot^{-1}, T_3 = CD 80g pot^{-1} and T_4 = PM 80g pot^{-1}. Values within columns followed by same letters do not differ significantly at 5% level by DMRT.

Table 3. Effects of Lime, CD and PM as a soil amendment on cadmium content in stover (μg g-1)

Treatment	Kalma		Sonatola	
	1st year	2nd year	1st year	2nd year
T_1	5.85a	5.68a	5.68a	5.44a
T_2	4.58b	4.36b	4.33b	4.18b
T_3	4.26c	4.14c	3.82c	3.68c
T_4	3.75d	3.68d	3.58d	3.44d
CV (%)	2.52	2.14	3.26	2.46
SE (±)	0.17	0.11	0.08	0.12

T_1= No amendment (Control), T_2= Lime 10g pot^{-1}, T_3= CD 80g pot^{-1} and T_4 = PM 80g pot^{-1}. Values within columns followed by same letters do not differ significantly at 5% level by DMRT.

Metal absorption by plants is pH dependent and therefore liming is a useful way of reducing the toxicity of Cd (Dinesh-Mani *et al.*, 2007; Liu *et al.*, 2011). Liming reduced Cd uptake significantly mainly due to immobilization of soil Cd (WangNeng *et al.*, 2011). The beneficial effect of lime in counteracting the Cd toxicity may be attributed to the decreased solubility and mobility of the Cd in soil.

Conclusion

Management practices like soil amendment using organic source is time demanding to reduce Cd concentration in soil and plant. The result of the present study indicated that poultry manure (PM) is a suitable organic amendment to minimize Cd concentration in soil and plant. Therefore, PM can be used as an organic amendment to produce Cd-safe maize production in contaminated soils.

References

Arao T, Ae N. 2003. Genotypic variations in cadmium levels of rice grain. Soil Science Plant Nutrition **49,** 473-479.

Arao T, Ae N, Sugiyama M, Takahashi M. 2003. Genotypic differences in cadmium uptake and distribution in soybeans. Plant Soil **25**, 247-253.

Azeez JO, Oyedeji SO, Shokalu AO. 2008. Ameliorative effects of poultry manure on cadmium toxicity to maize (*Zea mays*). Agriculture and Environment **8**(1/2), 74-82.

Black CA. 1965. Methods of Soil Analysis, Part 1, Agron. Monograph. 9. ASA Madi., Wiscon., USA.

Bray RH, Kurtz T. 1945. Determination of total organic and available forms of phosphorus in soils. Soil Science **59**, 39-45.

Bremner JM, Mulvaney CS. 1982. Total nitrogen, In: Methods of Soil Analysis, Part 2, 2nd Ed, Page, A.L. Miller, RH and Keeney, DR Amer. Soc. Agron. Inc. Madi., Wiscon., USA. pp. 599-622.

Dinesh-Mani, Chitranjan-Kumar, Srivastava RK. 2007. Effect of calcium, zinc and organic matter on the uptake of cadmium in *Brassica rapa* L. (Turnip). Proceedings-of-the-National-Academy-of-Sciences-India-Section-B,-Biological-Sciences 77(3), 263-276.

Fox RL, Olsen RA, Rhoades HF. 1964. Evaluating the sulphur status of soil by plant and soil test. Soil Science American Proceeding **28**, 243-246.

Ghosh AB, Bajaj JC, Hasan R, Sing D. 1983. Soil and Water Testing Methods. A Laboratory Manual, Division of Soil Science and Agricultural Chemistry. IARI, New Delhi 110012.

Gomez KA, Gomez AA. 1984. Statistical Procedures for Agricultural Research. Int. Rice Res. Inst. John Wiley & Sons, NY.

HanSong C, QiaoYun H, LiNa L, Peng C, Wei L, Ming L. 2010. Poultry manure compost alleviates the phytotoxicity of soil cadmium: influence on growth of pakchoi (*Brassica chinensis* L.). Pedosphere **20**(1), 63-70.

Hong CD, Lee DK, Kim PJ. 2008. Feasibility of phosphate fertilizer to immobilize cadmium in a field. Chemosphere **70**, 2009-2015.

Khan SI, Ahmed AKM, Yunus M, Rahman M, Hore SK, Vahter M, Wahed MA. 2010. Arsenic and cadmium in food-chain in Bangladesh an exploratory study. Journal Health Population Nutrition **28**(6), 578-584.

Kukuchi T, Okazaki M, Toyota K, Motobayashi T, Kato M. 2007. The input-output balance of cadmium in a paddy field of Tokyo. Chemosphere **67**, 920-927.

Lindsay WI, Norvell WA. 1978. Development of DTPA soil test for Zn, Fe, Mn and Cu. Soil Science Society America **42**, 421-428.

Liu ZB, Ji XH, Tian FX, Peng H, Wu JM, Shi LH. 2011. Effects and mechanism of alkaline wastes application and zinc fertilizer addition on Cd bioavailability in contaminated soil. China Journal of Environment Science **32**, 1164–1170.

Loganathan P, Vigneswaran S, Kandasamy J, Naidu R. 2012. Cadmium sorption and desorption in soils: a review. Crit. Review Environment Contamination Toxicology **42**, 489–533.

Meharg AA, Norton G, Deacon C, Williams P, Adomako EE, Price A, Zhu Y, Li G, Zhao FJ, McGrath S, Villada A, Sommella A, De Silva PMCS, Brammer H, Dasgupta T, Islam MR. 2013. Variation in rice cadmium related to human exposure. Journal of Environmental Science & Technology **47**, 5613-5618.

Naidu R, Kookana RS, Sumner ME, Harter RD, Tiller KG. 1997. Cadmium sorption and transport in variable charge soils: a review. Journal of Environmental Quality **26**, 602–617.

Naser H, Shill N, Mahmud M, Rashid M, Hossain K. 2009. Lead, cadmium and nickel contents of vegetables grown industrially polluted and non-polluted areas of Bangladesh. Journal Agricultural Research **34**(4), 545-554.

Nelson DW, Sommers LE. 1982. Total carbon, organic carbon and organic matter, In: Methods of Soil Analysis, Part 2, 2nd Ed, Page, A.L. Miller, RH and Keeney, DR Amer. Soc. Agron. Inc. Madi., Wiscon., USA. pp. 539-580.

Ok YS, Lee SS, Jeon WT,Oh SE,Usman ARA, Moon DH. 2011. Application of eggshel waste for the immobilization of Cd and Pb in a contaminated soil. Environment Geochemical Health **33**, 31-39.

Ok YS, Lim JE, Moon DH. 2010 a. Stabilization of Pb and Cd contaminated soils and soil quality improvement using waste oyster shells. Environment Geochemical Health **33**, 83-91.

Ok YS, Oh SE, Ahmed M, Hyun S, Kim KR, Moon DH, Lee SS, Lim KJ, Jeon WT, Yang JE. 2010 b. Effects of natural and calcine oyster shells on Cd and Pb immobilization in contaminated soils. Environment Earth Science **61**, 1301-1308.

Olsen SR, Sommers LE. 1982. Phosphorus, In: Methods of Soil Analysis, Part 2, 2nd Ed, Page, A.L. Miller, RH and Keeney, DR. Amer. Soc. Agron. Inc. Madi., Wiscon., USA. pp. 403-427.

Page AL, Miller RH, Keeney DR. 1982. Methods of Soil Analysis. Part-2. Chemical and Microbiological Properties. 2nd edition. Am. Soci. Agron. Inc. Soil Sci. Soc. Am. Inc. Madi., Wiscon., USA. pp. 403-430.

Peterson ML. 2002. Arsenic distribution in pore waters and sediments of Puget sound, lake, Washington, the Washington coast and seanich inlet, BC geochemical et cosmochemica Acta **50**, 353-369.

Rhoades JD. 1982. Cation exchange capacity. In: Methods of Soil Analysis, Part 2, 2nd Ed, Page, A.L. Miller, RH and Keeney, DR Amer. Soc. Agron. Inc. Madi., Wiscon., USA.

Tandy S, Healey JR, Nason MA, Williamson JC, Jones DL. 2009. Remediation of metal polluted mine soil with compost: Co-composting versus incorporation. Environment Pllution **157**, 690-697.

UNB. 2011. Core people suffering from kidney diseases in Bangladesh; experts. Available from: http;/www unbconnect.com/component/news/task-show/id 43116. Accessed Sept. 26, 2011.

Uraguchi S, Fujiwara T. 2012. Cadmium transport and tolerance in rice: perspectives for reducing grain cadmium accumulation. Rice Science **5**(5), 3-8.

WangNeng T, ZhiAn L, Jing Q, Bi Z, NingYu L, Ping Z, Gang W. 2011. Lime and phosphate could reduce cadmium uptake by five vegetables commonly grown in South China. Pedosphere **21**(2), 223-229.

XiaoFang G, ZeBin W, QiTang W, JinRong Q, JianLi Z. 2011. Cadmium and zinc accumulation in maize grain as affected by cultivars and chemical fixation amendments. Pedosphere **21**(5), 650-656.

Yassen AA, Nadia, Badran M, Zaghloul SM. 2007. Role of some organic residues as tools for reducing heavy metals hazard in plant. World-Journal-of-Agricultural-Sciences **3**(2), 204-209.

Yoshida S, Forno AD, Cock JA, Gomez KA. 1976. Physiological Studies of Rice. 2nd Eds. Int. Rice Research Inst. Manila, Philippines.

Yost KJ, Mites LJ, Parsons TW. 1980. In: Cadmium- A case study. Environment International **3,** 473-484.