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Research Article

Effect of Lime and Farmyard Manure on the Concentration of Cadmium in Water Spinach (*Ipomoea aquatica*)

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An experiment was conducted to investigate the effect of lime and farmyard manure on the concentration of cadmium in water spinach. Water spinach (*Ipomoea aquatica* cv. Kankon) was grown in sandy loam soil spiked with 5 mg Cd Kg^{-1} with lime (L) and farmyard manure (M) amendments. The treatments consisted of control, four levels of L (5, 10, 15, and 20 t ha^{-1}), M (5, 10, 15, and 20 t ha^{-1}), and their combinations ($5+5$, $10+10$, $15+15$, and $20+20$ t ha^{-1}). Growth parameters of water spinach increased significantly with the addition of lime and farmyard manure in the soil. Lime addition to soil decreased Cd concentration in both shoot and root of water spinach. In control ($0+0$), Cd concentration was 62.67 mg kg^{-1} in shoot, and 135.5 mg kg^{-1} in root. Cadmium concentration decreased by 72, 15, and 66% over the control in shoot and 82, 28, and 76% in the roots correspondingly with the highest rate of lime (20 t ha^{-1}), manure (20 t ha^{-1}), and lime plus manure combinations (20 t ha^{-1} + 20 t ha^{-1}). The results imply that 5 to 10 t ha^{-1} lime could be used in Cd-contaminated soils to reduce Cd uptake by agricultural crops.

1. Introduction

Intensive industrial activities and agricultural development can usually cause environmental problems due to heavy metal contamination. Under natural conditions, concentration of heavy metals, especially cadmium (Cd) is low in soils, except in those derived from shales [1]. Considerable amount of Cd can be introduced into soils via anthropogenic pathways such as dumping industrial effluents, agricultural application of sewage sludge [2], and the addition of commercial fertilizers [3]. Cadmium is not essential to biota and it is toxic to human at lower concentrations than those toxic to plants. Its effect on humans is cumulative. Crops grown on Cd-contaminated soils are one of the sources of Cd transport to humans [4]. The limit of cadmium concentration in soil associated to biomass reduction for the majority of agricultural plants is reported to be between 5 and 15 mg Cd kg^{-1} of soil [5]. Growth reduction of lettuce by 23% by the addition of 4 mg Cd kg^{-1} was found in a loamy sand soil [6].

Therefore, it is necessary to develop techniques to treat and stabilize heavy metals in situ in an effective and cost effective manner [7]. An approach towards this is to render the metals immobilized by using different amendments. Lime, phosphates, or organic matter residues are commonly employed for metal immobilization in soils [8]. Lime is often chosen because it changes the forms of the metals rendering them less bioavailable. Liming is a well-known practice for controlling uptake of Cd by plants [9, 10]. It was found that the addition of lime decreased the Cd concentration in rice by 25% [11]. In another experiment it was found that lime plus Zn fertilizer strongly reduced cadmium uptake by lettuce [12].

Some scientists found that application of commercial MgO into a Cd-contaminated paddy soil reduced the Cd uptake effectively [13]. The effect lies in the rise of soil pH which decreases Cd availability through increasing Cd adsorption. The rise in pH due to liming leads Cd^{2+} to form $Cd(OH)^+$· $Cd(OH)^+$ has a strong affinity to soil adsorption sites compared with Cd^{2+} [14, 15]. However, increasing pH does not always reduce plant uptake of Cd [16, 17]. Little or no effect of liming on Cd uptake by crops was reported [18, 19].

Organic matter in soil strongly influences the bioavailability of Cd. Addition of farmyard manure may be a strategy to reduce the accumulation of Cd in edible crops [20, 21]. However, Narwal and Singh [22] suggested that the efficiency of the organic material in reducing Cd uptake was generally small. On the contrary, Hanč et al. [23] found that addition of manure increased cadmium uptake by plants. Again, Li et al. [24] found that pig, dairy cow, and chicken manures contained high Cd due to presence of Cd in their feeds.

However, earlier investigations were done to study the effects of an amendment separately, and very little has so far been understood on the interaction of farmyard manure and lime on the bioavailability and uptake of Cd by plants. On this background, the present experiment was undertaken to investigate the effect of farmyard manure and lime on the growth and concentration of Cd in water spinach. Water spinach was chosen as the test plant because it is an important vegetable crop often found growing in contaminated soils.

Table 1: Properties of soil and farmyard manure.

Properties	Soil	Farmyard manure
Sand	68%	—
Silt	14%	—
Clay	18%	—
pH	5.3	6.8
Organic carbon	0.71%	25%
Total N	0.10%	1.88%
CEC	6.02 cmol kg^{-1}	—
Total P	0.03%	0.35%
Total K	0.24%	1.79%
Total Cd	Below the detection limit (0.03 mg kg^{-1})	0.30 mg kg^{-1}
Total Pb	7.4 mg kg^{-1}	—
Total Zn	57 mg kg^{-1}	—
Total Mn	190 mg kg^{-1}	—

2. Materials and Methods

A pot experiment was conducted at the crop field of the Department of Soil Science, University of Chittagong, Bangladesh using a sandy loam surface soil. Uncontaminated soil samples were collected from nearby field, air-dried, ground and passed through 4-mm sieve for using it in the greenhouse experiment. For laboratory analysis, a subsample was air-dried and passed through a 2-mm sieve and stored. Soil texture was determined by hydrometer method [25]. Soil pH was measured in a 1 : 2.5 soil-to-water suspension, organic carbon by Walkley and Black [26], and cation exchange capacity (CEC) by extraction with neutral 1 M NH_4OAc [27]. Total nitrogen of soil and farmyard manure was determined by micro-Kjeldahl method as described by Jackson [28]; total phosphorus, potassium, lead, zinc, iron, and manganese were measured by AAS (Varian AA-220) after digestion with aqua regia [29].

Thirty nine plastic pots of 5 L capacity were taken. Four-kilogram air-dry soil was placed in each pot. Thirteen treatments: one control, four levels of lime (L = 5, 10, 15, and 20 t ha^{-1}), four levels of farm yard manure (M = 5, 10, 15, and 20 t ha^{-1} $CaCO_3$), and four of their combinations $(5+5, 10+10, 15+15, \text{and } 20+20)$ were given to the pots. The treatments were replicated three times. The pots were arranged in a completely randomized design. In each pot soil, Cd as $3CdSO_4 \cdot 8H_2O$ in solution form was added at the rate of 5 mg kg^{-1}. Cd was added once prior to the experiment. Important properties of soil and farmyard manure used are presented in Table 1. Five water spinach (*Ipomoea aquatica* cv. Kankon) seeds were sown to each pot. One week after emergence, 3 seedlings were retained. Plants were irrigated as and when necessary. The plants were harvested after 45 days of growth and separated into shoots and roots. The number of leaves and plant height were recorded at the harvest. Shoots and roots were washed thoroughly first with tap water to remove adhering soil particles and then with distilled water. The plant parts were dried in an oven at 65°C for 72 hours and dry mass was recorded. Plant samples were grounded in a stainless steel grinder. Plant sample was digested with nitric-perchloric acids [30] and Cd concentration in the digest was measured by Atomic Absorption Spectrophotometer (Varian spectra AA- 220). MINITAB program [31] was used for statistical analysis of data using General Linear Model (GLM) procedure.

3. Results

Plant growth parameters, cadmium concentrations in roots and in shoots of water spinach, and soil pH were affected by lime and farmyard. The interaction of lime and farmyard manure was not found significant in most cases (Table 2).

3.1. Growth of Water Spinach. Height of plants after 45 days of growth varied from 44 cm in control to 64 cm in 20 t ha^{-1} lime plus 20 t ha^{-1} farmyard manure (L20 + M20) treated pots (Table 3). In these Cd spiked soils, both lime and manure similarly increased the height of plants, but height increased more when lime and manure were added at the highest dose. Similar response was found in the number of leaves. The total number of leaves per plant varied from 16 in control to 24 in 20 t ha^{-1} lime plus 20 t ha^{-1} farmyard manure (L20 + M20) treated pots. All the growth parameters showed an increasing trend with the increasing doses of lime and manure. Dry weight of shoot of water spinach ranged from 0.78 g $plant^{-1}$ in control to 3.83 g $plant^{-1}$ in 20 t ha^{-1} lime plus 20 t ha^{-1} farmyard-manure-treated pots. Dry weight of shoot increased sharply with the increase of doses of lime, manure, and combined lime plus manure. Among amendments, L plus M treatments yielded higher shoot dry matter (1.93 to 3.83 g $plant^{-1}$) than only lime treatments. Dry weight of shoot was relatively higher with manure treatment (2.42 to 2.90 g $plant^{-1}$) than with lime treatments (1.41 to 2.45 g $plant^{-1}$) when they were applied separately. Dry weight of root of water spinach also increased with an increase in rates of lime, manure, and lime plus manure treatments. Dry weight of root varied

Table 2: ANOVA (F values) of experimental parameters.

Sources of variation	Plant height	Number of leaves	Fresh weight of root	Fresh weight of shoot	Dry weight of root	Dry weight of shoot	Cd conc. in root	Cd conc. in shoot	Soil pH
Lime	15**	16**	8**	5*	6*	16**	98**	230**	156**
FYM	39**	23**	25**	63**	22**	53**	7*	ns	ns
Lime × FYM	ns	ns	ns	8**	ns	6*	ns	ns	ns

*,**Significant at $P < 0.05$ and $P < 0.01$, respectively; ns: not significant.

Table 3: Growth parameters of water spinach and soil pH after harvest.

Treatments	Plant height (cm)	Number of leaves	Fresh weight of shoot (g)	Fresh weight of root (g)	Dry weight of shoot (g)	Dry weight of root (g)	Soil pH
Control	44 e	16 e	7.40 f	1.42 f	0.78 i	0.73 g	5.36 c
L5 + M0	46 e	17 de	8.98 ef	1.81 f	1.41 h	0.95 fg	6.80 b
L10 + M0	48 de	17 de	10.53 de	2.02 f	1.93 g	1.07 f	7.47 ab
L15 + M0	49 de	18 cd	11.87 cd	2.41 e	2.24 fg	1.33 e	7.88 ab
L20 + M0	51 cd	19 c	12.38 c	2.82 de	2.45 ef	1.57 de	8.18 a
L0 + M5	47 de	18 cde	13.72 bc	2.24 f	2.42 ef	1.13 ef	5.42 c
L0 + M10	51 cd	18 cde	14.44 b	2.50 d	2.49 def	1.39 de	5.86 bc
L0 + M15	53 c	19 cd	15.65 ab	3.37 cd	2.76 cde	1.89 c	5.95 bc
L0 + M20	56 bc	19 c	15.83 ab	3.79 c	2.90 c	1.99 bc	6.08 bc
L5 + M5	52 cd	18 cd	10.83 d	2.18 e	1.93 fg	1.06 ef	7.01 b
L10 + M10	59 b	22 b	13.44 bc	3.44 c	2.67 cde	1.78 cd	7.71 ab
L15 + M15	62 ab	24 a	16.38 a	4.51 b	3.41 b	2.23 b	8.12 a
L20 + M20	64 a	24 a	17.25 a	5.20 a	3.83 a	2.66 a	8.3 a

Means followed by the same letter(s) in a column are not significantly different at $P < 0.05$.

from 0.73 g plant^{-1} in control to 2.66 g plant^{-1} in 20 t ha^{-1} lime plus 20 t ha^{-1} farmyard-manure-(L20 + M20) treated pots. Among amendments, lime plus manure treatments produced higher root dry matter (1.06 to 2.66 g plant^{-1}) and lime treatments (without M) had lower dry matter (0.95 to 1.57 g plant^{-1}) of root. Dry weight of root (1.13 to 1.99 g plant^{-1}) with manure treatments (without L) was between lime plus manure and lime treatments.

3.2. Soil pH. Soil pH values recorded after harvest of water spinach in soils of the different amendments are presented in Table 3. Soil pH of the control pot (5.36) did not change much but increased considerably in lime treated soils (6.80 in L5 + M0 to 8.18 in L20 + M0 treatments). On the other hand, manure without lime changed soil pH slightly (5.42 in L0 + M5 to 6.08 in L0 + M20). Combined application of lime and manure also increased pH to an appreciable extent (Table 3).

3.3. Cadmium Concentration in Water Spinach. Concentration of Cd in root, shoot, and total plant was the highest in the control pots. Application of lime abruptly reduced Cd concentration in shoot and root (Table 4). For example, concentration of Cd in shoot and root were 62.67 and 135.5 mg kg^{-1}, respectively, in the control pots. Application of 5 t ha^{-1} lime without manure reduced the concentration of Cd in shoot to 21.17 mg kg^{-1} and in root to 89.65 mg kg^{-1}. In the 20 t ha^{-1} lime treated pots, Cd concentration in shoot was 17.58 mg kg^{-1}, indicating 72% reduction of Cd concentration compared to control. Manure also reduced Cd concentration in shoot and root but to a comparatively smaller extent than lime. In the 5 t ha^{-1} manure amended pots, there was a Cd concentration of 54.75 mg kg^{-1} in shoot of water spinach. Lime reduced more cadmium concentration in root than shoot. Addition of 20 t ha^{-1} reduced concentration of Cd in shoot to 24.26 mg kg^{-1}. In the case Cd concentration reduction, addition of lime was more effective than lime plus manure treatments (Table 4). Soil pH showed significant negative correlation with concentration of Cd both in the shoot ($r = -0.803$ and $P = 0.000$) and in the root ($r = -0.805$ and $P = 0.002$).

4. Discussion

In this study, growth of water spinach increased several folds with the application of farmyard manure in one hand, and decreased Cd concentration in the shoots and roots of water spinach many folds with the application of lime, on the other hand. Application of farmyard manure reduced negligible amount of Cd concentration in water spinach compared with lime.

The experimental soil was strongly acidic (pH 5.3), increased soil pH about 2 unit by liming. The benefit of

Table 4: Concentration of cadmium in water spinach in different treatments.

Treatments	Cadmium concentration in shoot ($mg\,kg^{-1}$)	Cadmium concentration in shoot (% over control)	Cadmium concentration in root ($mg\,kg^{-1}$)	Cadmium concentration in root (% over control)
Control	62.67 a	0	135.5 a	0
L5 + M0	21.17 b	66	89.65 c	34
L10 + M0	20.25 b	67	41.23 d	70
L15 + M0	21.83 b	65	34.93 d	74
L20 + M0	17.58 b	72	24.26 d	82
L0 + M5	54.75 a	13	128.50 a	5
L0 + M10	53.67 a	14	111.92 ac	17
L0 + M15	47.08 a	25	99.83 bc	26
L0 + M20	51.17 a	18	97.92 bc	28
L5 + M5	21.08 b	66	46.07 d	66
L10 + M10	21.67 b	65	36.56 d	73
L15 + M15	24.25 b	61	33.02 d	76
L20 + M20	21.83 b	65	32.86 d	76

Means followed by the same letter(s) in a column are not significantly different at $P < 0.05$.

liming may lie in enhancing essential nutrient availability due to raising soil pH. Farmyard manures are good source of plant nutrients and enhanced the growth of water spinach in this study. Higher reduction of Cd concentration in water spinach grown in lime, treated soils agreed with the findings of other investigators [9–11, 20, 32–35]. Increasing the soil pH by liming may cause immobilization of heavy metals [20] and reduce their availability in contaminated soils [32]. An experiment was conducted to examine the effect of liming on the accumulation of sludge-borne metals in the crop plants [33]. Their results showed that liming the soils to pH 7 prior to sowing significantly reduced metal concentrations in carrots and spinach, although the reduction appeared to be greater for Cd, Ni, and Zn than for Cu and Pb. Among various soil parameters known to affect the availability of Cd, soil pH was considered as the most important [34]. Cadmium concentration of the plant tissue generally decreased with increased soil pH provided that other soil properties remained unchanged. Soil pH also regulates Cd extractability in soils. The increase in soil pH increases the adsorption of Cd by soils and reduces its extractability [35].

In our study, the increase of soil pH by liming associated with the decrease of Cd concentration in water spinach. Less impact of farmyard manure on the reduction of Cd concentration in water spinach may be explained by the findings of other investigators [36–38] Kashem and singh [36] found significant positive correlation between mobile fraction of metals and organic matter. Almås et al. [39] reported that in a pig manure treated alum shale soil, ^{109}Cd and Zn^{65} increased significantly in mobile fractions, with a corresponding reduction in immobile fractions. Low molecular weight organic acids may inhibit the retention of metals in the solid phase and hence increase solubility. McBride [37] reported that soluble organics can increase the solubility of metal cations bound to organic molecules. In an experiment it was found that application of cow and pig manure decreased the Cd concentration in the exchangeable fraction of the soil [22]. The concentration of Cd in wheat grown in the cow manure-amended soil was lower as compared to that grown in the soil amended either with pig manure or peat soil, indicating that the source of organic matter was a determining factor for Cd distribution in the soil and for Cd uptake by plants. They concluded, however, that the efficiency of the organic material in reducing Cd uptake was generally small.

5. Conclusion

Growth of water spinach (*Ipomoea aquatica* cv. Kankon) and concentration of cadmium were influenced by lime, farmyard manure, and their combinations. It was found that lime was the most effective in reducing cadmium concentration in shoots and roots of water spinach. The underlying cause was the elevation of soil pH. The effect of farmyard manure was negligible in reducing Cd concentration but it increased biomass production of water spinach over lime mainly due to nutritional effects of farmyard manure. Application of lime could be recommended to be used to reduce Cd uptake by plants grown in Cd-contaminated acidic soils.

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