Research Article

Effect of FYM on the uptake of cadmium by Amaranth (Amaranthus viridis L.)

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Abstract: A field experiment was conducted to find out the effect of FYM on the uptake of cadmium by Amaranth (Amaranthus viridis L.) on the alluvial soil of Sheila Dhar Institute experimental farm, Allahabad, Uttar Pradesh. Four levels of organic matter (0, 10, 15 and 20 t ha^{-1}), Cd (0, 5, 10 and 15 mg kg^{-1}) were applied as FYM and $CdCl_2$, respectively. The application of FYM 20 t ha^{-1} increased the dry biomass of Amaranth by 35.08% over the control. The application of 15 mg kg^{-1} Cd maximum reduces dry biomass of Amaranth by 17.45% compared to control and registered the highest accumulation of Cd in shoot and root of Amaranth by 1.86 mg kg^{-1} and 1.92 mg kg^{-1}, respectively. Therefore, 20 t ha^{-1} FYM applications may be recommended to enhance dry biomass of Amaranth. The response of FYM was observed ameliorative in Cd-contaminated plots.

Key words: Cadmium, FYM, Amaranth, Uptake.

INTRODUCTION

The pollution of agricultural soils by heavy metals is widespread. Long-term sewage irrigation may lead to the accumulation of heavy metals in agricultural soils. Improper treatment and disposal of industrial wastewaters are major causes of soil contamination by heavy metals. Heavy metal toxicity is one of the oldest environmental problems and remains a serious health concern today. Cadmium (Cd) is common toxic heavy metals in the environment. The general public is exposed to Cd and Pb through the ambient air, drinking water, food, industrial materials and consumer products (Nordberg et al., 2011: Zhai et al., 2015).

Cd is not essential elements in metabolic processes in plants or animals, and they can accumulate to levels that are toxic or lethal to organisms. The threat of heavy metal pollution to public health and wildlife has led to an increased interest in developing systems that can remove or neutralize heavy metal toxic effects in soil, sediments and wastewater (Valls and Lorenzo, 2002). Among the heavy metals, cadmium (Cd) has been considered to be one of the most serious metal contaminants since the Itai-Itai disease reported in Japan. As a non-essential element for living organisms, Cd has a very high mobility in soil-plant systems, with propensity to adversely effect, both human health and the functioning of ecosystems (Perronnet et al., 2000).

The application of soil amendments to immobilize heavy metals is a promising technology to meet the requirements for environmentally sound and cost-effective remediation (Gupta et al., 2007). Soil amendments can help to: reduce labile contaminant pools, minimize organism exposure, promote plant development and limit migration to the groundwater (Kumpiene et al., 2008). The chemical stabilization methods were considered to be the most cost-effective ways to immobilize heavy metals in the soils (Chen et al., 2000). The influence of organic substances on the availability of the heavy metals depends on the nature of these metals, soil types and the organic matter properties, particularly the degree of humification (Walker et al., 2004). Organic matter has a vital role in controlling the mobility of heavy metals in soils. It may decrease the available concentrations of heavy metals in soils by precipitation, adsorption, or complexion processes (Bernal et al., 2007). Amaranth (Amaranthus viridis L.) belong to the Amaranthaceae family the leaves and seeds are edible and nutritious like any other amaranth.

Amaranthus viridis L. commonly called 'Choulai' in Hindi has been used leafy vegetable In Indian. The objectives of this study were to examine the effect of FYM and single super phosphate on the uptake of Cd and the effects on their respective concentration in roots and shoots dry biomass of Amaranth.

MATERIALS AND METHODS

Plant Material and Experimental Layout

The Sheila Dhar Institute experimental site, covers an area of 1 hectare, is located at Allahabad in northern India at 25°57' N latitude, 81°50'E longitude and at 120±1.4 m altitude. A sandy clay loam soil, derived from Indo- angetic alluvial soils, situated on the confluence of rivers Ganga and Yamuna alluvial deposit, was sampled for the study. The texture was sand (>0.2 mm) 55.54%, silt (0.002-0.2 mm) 20.32% and clay (<0.002 mm) 24.25%. The detailed physico-chemical properties of the investigated soil have been given in the table.

Table-1. Physico-chemical properties of the Sheila Dhar Institute (SDI) Experimental Farm, Allahabad, India

Parameters	Values
Texture: Sandy Clay Loam (Sand, Silt and Clay %)	(55.54,20.32 and 24.25, respectively)
pH	7.8
EC(dSm^{-1}) at 25^0C	0.28
Organic Carbon (%)	0.56
CEC [C mol (p^+) kg^{-1}]	19.8
Total Nitrogen (%)	0.08
Total Phosphate (%)	0.07
DTPA-extractable Cd (ppm)	0.26

Experimental

After systematic survey factorial experiment was conducted to study the effect of organic matter (FYM) on the uptake of cadmium by Amaranth (Amaranthus viridis L.). The experiment was replicated thrice and conducted in completely randomized block design following sixteen treatments. Total 48 plots (having 16 treatments replicated thrice) were installed. There were 48 plots, each plots having (1×1m^2 area). After 24 hr of the treatment seeds were sown in month of October. Soil moisture was maintained by irrigating the crops at interval of 5-6 days. Vegetables were harvested at 45 days after sowing (DAS). Each interaction was made with a heavy metals (having four doses: A_0, A_1, A_2 and A_3) and an ameliorants (having four doses: B_0, B_1, B_2 and B_3). The treatments of Cd × organic matter (FYM) relationship consisted of 0, 10, 15 and 20 tha^{-1} FYM along with 0, 5, 10 and 15 mg kg^{-1} Cd. The source of Cd and organic matter were $CdCl_2$ and FYM respectively. The interaction study was conducted at Sheila Dhar Institute experimental farm. In the experimental layout diagram 'A' stand for heavy metals (Cd) and 'B' stand for ameliorants (FYM). The treatment combinations have been mentioned under table:2.

TABLE-2: Effect of Cd × FYM interaction on dry biomass yield of Amaranth (g $plot^{-1}$)

Treatments Symbols	Treatments Cd (mg kg-1), FYM (t ha-1)	Replication			
		R_1	R_2	R_3	Mean
A_0B_0	Cd 0 + FYM 0	315.5	293.0	271.0	293.2
A_0B_1	Cd 0 + FYM 10	336.0	359.7	380.4	358.7
A_0B_2	Cd 0 + FYM 15	382.2	353.2	417.2	384.2
A_0B_3	Cd 0 + FYM 20	363.0	394.0	431.0	396.0
A_1B_0	Cd 5 + FYM 0	301.6	275.3	290.9	289.3
A_1B_1	Cd 5 + FYM 10	374.0	341.0	311.0	342.0
A_1B_2	Cd 5 + FYM 15	366.3	398.0	331.6	365.3
A_1B_3	Cd 5 + FYM 20	351.0	381.0	414.0	382.0
A_2B_0	Cd 10 + FYM 0	264.0	240.0	285.0	263.0
A_2B_1	Cd 10 + FYM 10	341.4	306.7	278.0	308.7
A_2B_2	Cd 10 + FYM 15	324.0	306.0	348.0	326.0
A_2B_3	Cd 10 + FYM 20	370.0	319.0	346.0	345.0
A_3B_0	Cd 15 + FYM 0	244.0	261.0	221.0	242.0
A_3B_1	Cd 15 + FYM 10	251.9	288.6	319.3	286.6
A_3B_2	Cd 15 + FYM 15	294.0	260.0	322.0	292.0
A_3B_3	Cd 15 + FYM 20	282.6	311.3	343.0	312.3

Soil Sampling

The larger fields were divided into suitable and uniform parts, and each of these uniform parts was considered a separate sampling unit. In each sampling unit, soil samples were drawn from several spots in a zigzag pattern, leaving about 2 m area along the field margins. Silt and clay were separated by Pipette method and fine sand by decantation (Chopra and Kanwar, 1999).

Extraction for Cadmium (Cd) Content in Soil

For total Cd content, one gram of soil was mixed in 5 ml of HNO_3 (16M, 71%) and 5 ml of $HClO_4$ (11 M, 71%). The composite was heated up to dryness. The volume was made up to 50 ml with hot distilled water. The samples were filtered using Whatman filter paper 42 (42.5mm). The clean filtrate was used for the estimation of cadmium using Atomic Absorption Spectrophotometer (AAS) (AAnalyst600, PerkinElmer Inc., MA, USA) (Kumar and Mani, 2010).

Soil physico-chemical analysis

Soil pH was measured with 1:2.5 soil water ratio using Elico digital pH meter (Model LI127, Elico Ltd., Hyderabad, India) at authors' laboratory. Double distilled water was used for the preparation of all solutions. Organic carbon was determined by chromic acid digestion method, cation exchange capacity (CEC) by neutral 1 N ammonium acetate solution, total nitrogen by digestion mixture (containing sulphuric acid, selenium dioxide and salicylic acid) using micro-Kjeldahl method, Glass Agencies, Ambala, India. Total phosphorus by hot plate digestion with HNO_3 (16M, 71%) and extraction by standard ammonium molybdate solution (Chopra and Kanwar 1999; Kumar and Mani 2010).

Plant analysis

Crop was harvested after 45 days. Samples were carefully rinsed with tap water followed by 0.2 % detergent solution, 0.1N HCl, de-ionized water, and double distilled water. Samples were dried in a hot-air oven at a temperature of 60 °C and ground to a fine powder. Plant dry biomass weight was recorded. One gram of ground plant material was digested with 15 ml of tri-acid mixture (Kumar and Mani, 2010) containing conc. HNO_3 (16M, 71%), H_2SO_4 (18M, 96%) and $HClO_4$ (11M, 71%) in 5:1:2), heated on hot plate at low heat (60°C) for 30 minutes and cadmium were determined by the Atomic Absorption Spectrophotometer (AAnalyst600, PerkinElmer Inc., MA, USA).

Statistical Analysis

Data were analyzed by factorial analysis of variation (ANOVA) using various treatments as independent factors with the help of the sum of square (SS) and degree of freedom (DF). The standard error=n V SE number of replications, and the critical difference (CD) is given by CD = $SE_{diff.}$ × $t_{5\%}$ ($t_{5\%}$= 2.042 at DF_{error}= 30 was observed) and standard deviation (SD) were determined in accordance with (Motulsky and Christopoulos, 2003).

RESULTS AND DISCUSSION

Effect of Cd × FYM interaction on dry biomass yield of Amaranth

The data presented in the Table -2 indicated almost similar trend that single application of 20 t ha^{-1} FYM produced maximum dry biomass of Amaranth up to the extent of 396 g $plot^{-1}$, which were recorded 35.08% increase over the control plot. Application of 20 t ha^{-1} FYM at different levels of Cd (5, 10 and 15 mg kg^{-1}) treated plots produced dry biomass of Amaranth 382, 345 and 312.3 g $plot^{-1}$, resulted in 30.30%, 17.68% and 6.53% increase over the control plots. The present study clearly showed ameliorative role of FYM on the dry biomass yield of Amaranth (Putwattana et al., 2015; Mani et al., 2014a; Josi et al., 2011; Hanc et al., 2008). The application of Cd at 15 mg kg^{-1} registered the minimum dry biomass of Amaranth up to 242 g $plot^{-1}$ showing maximum retardation in growth to the extent of 17.45% over the control due to the presence of excess Cd in the root environment. The entry of Cd into the plants must be monitored to minimize the possible risk of the metals toxicity into the plants. The main observable effect of Cd on leafy vegetables was decreased dry matter yields with increasing Cd levels in comparison with those of the controls, which was likely due to the deleterious effect of Cd on numerous plant physiological processes. Mensah et al., (2008); Joshi et al., (2011); Mani et al. (2014b); Putwattana et al., (2015) has also reported similar findings.

Effect of Cd × FYM interaction on the uptake of Cd in shoot and root of Amaranth

The data (Fig.-1& 2) indicated that the effect of Cd, FYM and Cd × FYM interaction were observed significant. Uptake of Cd in shoot and root of plants significantly increased and indicated greater relative uptake of Cd from control to Cd added plots. Application of 15 mg kg^{-1}

Cd of increased maximum uptake of Cd in shoot and root of Amaranth by 1.86 mg kg^{-1} and 1.92 mg kg^{-1}, respectively (Fig.-1 & 2). Application of Cd 15 mg kg^{-1} + FYM 20 t ha^{-1} decreased the uptake of Cd 0.92 mg kg^{-1} and 0.94 mg kg^{-1} in shoot and root of Amaranth compared to non-amended plot, respectively. Added single doses of FYM 20 t ha^{-1} decrease maximum uptake of Cd in shoot and root of Amaranth by 0.02 and 0.04 mg kg^{-1} compared to control plots, respectively. Organic matter (FYM) has a vital role in controlling the mobility of heavy metals in soils. It may decrease the available concentrations of heavy metals in soils by precipitation, adsorption, or complexion processes. Putwattana et al., 2015; Bolan et al., 2003; Park et al., 2011, also reported almost similar findings. The uptake of metals from the soil to plant depends on different factors such as their soluble salt content in it, soil pH, plant growth stage types of species, fertilizer and soil (Sharma et al., 2006; Ismail et al., 2005; Putwattana et al., 2015).

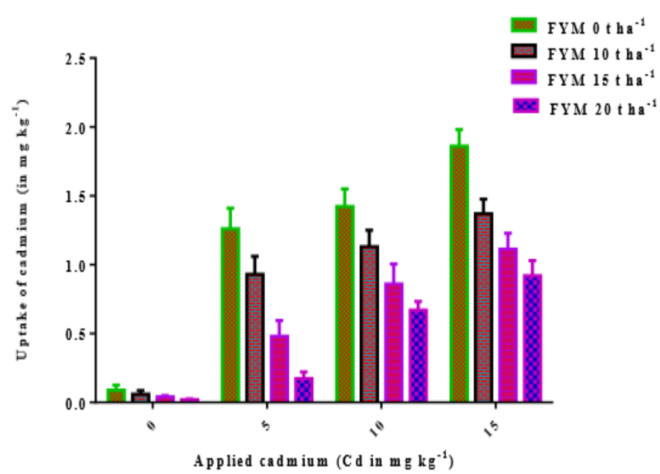

Fig:-1: Effect of Cd × FYM interaction on the uptake of Cd in shoot of Amaranth (mg kg-1).

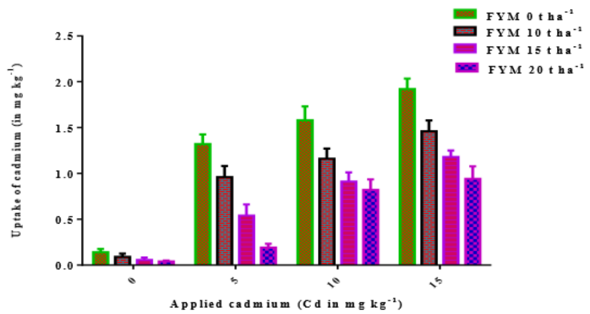

Fig.-2: Effect of Cd × FYM interaction on the uptake of Cd in root of Amaranth (mg kg-1).

CONCLUSION

FYM treated plots registered the highest dry biomass yield of Amaranth by 35.08%. Application of FYM @ 20 t ha^{-1} was found most effective in boosting the dry biomass content of crop. Cd @ 15 mg kg^{-1} influenced the dry biomass content diminutively, which was recorded 17.45% decrease over the control plots in Amaranth. Application of Cd 15 mg kg^{-1} of increased the highest uptake of Cd in shoot and root of Amaranth by 1.86 mg kg^{-1} and 1.92 mg kg^{-1}, respectively.

The reduced uptake of Cd was observed in FYM treated plots. An ameliorative effect of FYM was observed in Cd-contaminated soil. The results of presented study showed that FYM can effectively immobilize Cd in the soil. FYM has potential to reduce Cd uptake in both shoot and root of the Amaranth plants.

The application of FYM to the soil possibly reduces Cd in the edible parts of the plants and helps to reduce the risk to the health of people living in metal contaminated areas. A more detailed study is required to grow Amaranth or other vegetable crops in metals- contaminated areas and evaluate their growth and uptake of heavy metals in different edible parts of plants.

In view of the uncertainties that remain about the behavior and effects of Cd in the food chain, it is desirable to minimize its concentration in crops that are grown on sewage- irrigated soils.

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REFERENCES

1. Bernal M.P., Clemente R., Walker D.J. (2007). The role of organic amendments in the bioremediation of heavy metal-polluted soils In: Gore RW (ed) Environmental research at the leading edge. Nova Science Publishers Inc., New York, pp. 1–57.
2. Bolan, N.S., Adraino, D.C., Duraisamy, A. and Mani, P. (2003). Immobilization and phytoavailability of cadmium in variable charge soils: III. Effect of biosolid addition. Plant Soil, 256: 231. http://link.springer.com/article/10.1023%2FA%3A1026288021059#page-1
3. Chen Z.S., Lee G.J., Liu J.C. (2000). Chemical methods and phytoremediation on soil contaminated with heavy metals. Chemosphere 41:229–234. http://www.sciencedirect.com/science/article/pii/S0045653599004154
4. Chopra, S.L. and Kanwar, J.S. (1999). Analytical Agricultural Chemistry, Kalyani Publication, New Delhi.
5. Gupta A.K., Dwivedi S., Sinha S., Tripathi R.D. (2007). Metal accumulation and growth performance of Phaseolus vulgaris grown in fl y ash amended soil. Bioresour Technol, 17:3404–3407. http://www.ncbi.nlm.nih.gov/pubmed/17451948
6. Hanc, A., Tlustos, P., Sjakova, J. and Balik, J. (2008).The influence of organic fertilizers application on phosphorus and potassium bioavailability. Plant Soil Environ. 54 (6): 247-254. Ismail, B.S., Farihah, K. and Khairiah, J. (2005). Bioaccumulation of heavy metals in vegetables from selected agricultural areas. B. Environ. Contam. Tox., 74, 320-327.
7. Joshi D., Srivastava, P. C. and Srivastava, P. (2011). Toxicity Threshold Limits of Cadmium for Leafy Vegetables Raised on copper, nickel and zinc in soil. Pedologist, 249-256. http://iuss.org/19th%20WCSS/Symposium/pdf/0686.pdf
8. Kumar, C. and Mani, D. (2010). Enrichment and management of heavy metals in sewage-irrigated soil. Lap LAMBERT Acad. Publishing, Dudweiler (Germany). http://www.abebooks.com/book-search/isbn/3838398939/
9. Kumpiene J., Lagerkvist A., Maurice C. (2008). Stabilization of As, Cr, Cu, Pb and Zn in soil using amendments – a review. Waste Manag, 28: 215-225.7 http://www.sciencedirect.com/science/article/pii/S0956053X07000165

10. Mani, D., Balak, S., Patel, N.K., Mourya, V. K. and Pal, N. (2014a). Effect of compost and single super phosphate on the uptake of cadmium by Radish (Raphanus sativus L.). J. Indian Chem. Soc., 91: 721-727. https://www.researchgate.net/publication/264417946_Effect_of_compost_and_single_super_phosphate_on_the_uptake_of_cadmium_by_Radish_Raphanus_sativus_L
11. Mani, D., Mourya, V. K., Balak, S., Patel, N.K. and Pal, N. (2014b). Effect of organic matter on the uptake of cadmium by Spinach (Spinacea oleracea L.). Asian J. Adv. Basic Sci., 3(1), 144-150.
12. Mensah, E., Allen, H.E., Shoji, R., Odai, S.N., Kyei-Baffour, N., Ofori, E. and Mezler, D., (2008). Cadmium (Cd) and Lead (Pb) Concentrations Effects on Yields of Some Vegetables Due to Uptake from Irrigation Water in Ghana. nt. J. Agr. Res., 3: 243-251. http://scialert.net/abstract/?doi=ijar.2008.243.251
13. Motulsky H. J. and Christopoulos A. (2003). GraphPad Software Inc, San Diego CA.
14. Nordberg, G.F.; Nogawa, K.; Nordberg, M.; Friberg, L.T. Foreword: Metals—A new old environmental problem and Chapter 23: Cadmium. In Handbook on the Toxicology of Metals, 3rd ed.; Nordberg, G.F., Fowler, B.A., Nordberg, M., Friberg, L.T., Eds.; Academic Press: Burlington, MA, USA, (2011); pp. vii, 446–451, 463–470, 600–609.
15. Park, J., Panneerselvam, P., Lamb, D., Choppala, G. and Bolan, N. (2011). Role of organic amendments on enhanced bioremediation of heavy metal (loid) contaminated soils. J. Hazard. Mater., 185: 549-574. http://www.ncbi.nlm.nih.gov/pubmed/20974519
16. Perronnet, K., Schwartz, C., Gerard, E., Morel, J.L. (2000). Availability of cadmium and zinc accumulated in the leaves of Thlaspi caerulescens incorporated into soil. Plant Soil 227, 257-263.
17. Putwattana, N., Kruatrachue, M., Kumsopa, A. and Pokethitiyook, P. (2015). Evaluation of organic and inorganic amendments on maize growth and uptake of Cd and Zn from contaminated paddy soils. Int. J. Phytoremediat., 17(2):165-74.
18. Sharma, R.K., Agrawal, M. and Marshall, F. (2006). Heavy metals contamination in vegetables grown in waste water irrigated areas of Varanasi, India. B. Environ. Contam. Tox., 77: 312-318. Valls, M., Lorenzo, V.D. (2002). Exploiting the genetic and biochemical capacities of bacteria for the remediation of heavy metal pollution. FEMS Microbiol. Rev., 26, 327–338.
19. Walker D.J., Clemente R., Bernal P. (2004). Contrasting eff ects of manure and compost on soil pH, heavy metals availability and growth of chenopodium album in a soil contaminated by pyritic mine waste. Chemosphere 57:215–224 Zhai, Q., Narbad, A., Chen, W. (2015). Dietary Strategies for the treatment of cadmium and lead toxicity. Nutrients, 7, 552-571.