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Effect of Organic Matter on the uptake of Cadmium by Spinach (*Spinaceaoleracea* L.)

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ABSTRACT: A field experiment was conducted to find out the effect of organic matter on the uptake of cadmium by Spinach (*Spinaceaoleracea* L.) on the alluvial soil of Sheila Dhar Institute experimental farm, Allahabad. Three levels of organic matter (0, 10 and 20 t ha^{-1}), Cd (0, 5 and 10 mg kg^{-1}) were applied as compost and $CdCl_2$, respectively. Addition of 20 t ha^{-1} organic matter increased the maximum dry biomass yield of Spinach by 36.5% over the control. The application of 10 mg kg^{-1} Cd maximum reduces dry biomass yield of Spinach by 27.8% over the control and registered the highest accumulation of Cd in shoot of Spinach by 5.7 fold over the control. Therefore, 20 t ha^{-1} organic matter applications may be recommended to enhance biomass yield of Spinach and Phytoremediation of Cadmium–contaminated soil through soil-plant-rhizospheric processes.

Keywords: Cadmium; compost; spinach; uptake.

INTRODUCTION

Although the heavy metals occur naturally in the soils having formed by the geological processes (such as alteration and weathering of rock), their enriched concentrations in the soils are regarded as great environmental hazard which is mainly due to the mining activities and the industrial in urban area. Hence, the effects of such increased heavy metal concentrations, especially in the soil environment and consequently on the human health, have become a critical topic in the recent past in order to control the soil heavy metal pollution in a sustainable manner. Application of organic residues as a source of organic matter is a common practice to improve physical, chemical and biochemical properties of soil[1-4] and is also an effective way to dispose of organic solid wastes.[5-8]. A large amount of dissolved organic matter (DOM) is immediately and significantly, presented after organic residues are added to soil.[9-11] Composting is the purposeful biodegradation of organic matter where the decomposition is carried out by microorganisms mostly bacteria, fungi and yeasts, while vermicomposting is a mesophilic process of ingestion, digestion and absorption of organic waste carried out by earthworms followed by excretion of castings. It is the metabolic process of earthworms, during which the metabolites are released from the alimentary canal and added to the castings, which enhances the levels of plant nutrients of organic waste and acts like plant growth promoters.[12-13] As a consequence, vermicompost or organic matter possesses relatively higher and more soluble and form of major nutrients – nitrogen, phosphorus, potassium, calcium and magnesium[14-15] compared with the parent materials and compost. Organic matter as like Compost and vermicompost are often considered supplements to chemical fertilizers and when applied releases the macro- and micronutrients slowly synchronizing with the required of plants. However, the presence of certain persistent hazardous chemical contaminants and pollutants, such as heavy metals in urban wastes and their composts and vermicompost, is a limiting factor that restrains wider use of compost and vermicompost of urban wastes.[16] Cadmium (Cd) is a non-essential element for almost all biota with the exception of *Thalassiosiraweissflogii* (Grunow) G. Fryxell et Hasle, a marine diatom that uses Cd as a substitute for zinc (Zn) in the metallo enzyme carbonic anhydrase.[17] The significant factors influencing the availability of heavy metals are soil pH and the quality of soil organic matter.[18-19] Heavy metals are of immense concern in the environment because of their eco-toxicity to plants and animals including human beings.[20] The removal of toxic heavy metals from waste had appeared as a major challenge for environmental managers and technologists. Some of the heavy metals, e.g. Zn, Cu, Mn and Ni, may be essential micronutrients for plants, animals and humans, while other highly toxic ones, e.g. Hg, Cd, As and Pb, are not known to have any positive nutritional effects. All of the heavy metals may cause toxic effects when occurred in undue concentrations, some of them even at a low concentration. Most of the heavy metals are non essential elements for plants but can be readily taken up and accumulated in various plant parts, as the metals are persistent and non-biodegradable, and poses serious health issues to the human body through food chains.[21]

The present investigation was carried out in order to find out the ability of the organic matter for reducing the uptake of Cadmium by a spinach plant (*Spinaceaoleracea* L.) growing in a soil added with Cadmium.

MATERIAL AND METHODS

Experimental Site: The experimental site is situated in northern India at 25º57'N latitude and 81º50'E longitude on south-east facing slopes of comparable inclination at altitudes between 200 and 80 m above sea level. A sandy clay loam soil, derived from sewage-sludge irrigated Indo-Gangetic alluvial soils of SDI farm situated on the confluence of Ganga and Yamuna alluvial deposit, was sampled from Allahabad city, India. The properties of the soil were: pH 8.0, EC 0.28 dSm^{-1}, organic matter ($K_2Cr_2O_7$ oxidation) 5.6 g kg^{-1}, total N 0.08 %, total P 0.04 %, CEC 19.8 C mol (P) kg^{-1}, and DTPA– Cd 0.38 mg kg^{-1}. The texture comprised of sand (>0.2 mm) 56.0 %, silt (0.002–0.2 mm) 20.0 % and clay (<0.002 mm) 24.0 %.

Soil analysis:

Preparation of DTPA solution: Di-ethyl thiamine penta acetic acid (DTPA) solution was prepared by a method developed by Lindsay and Norvell used to extract the available heavy metals in soil samples.[22]

Extraction of soil with DTPA solution: Five gram soil and 20ml DTPA solution was added and the contents were shaken for two hours and then filtrate through Whatman filter paper No. 42. The clean filtrate was used for the estimation of Cd by Atomic Absorption Spectrophotometer.

Soil pH was measured with 1:2.5 soil water ratio using ELICO pH meter (Model LI 127) at Laboratory of Sheila Dhar Institute of Soil Science, University of Allahabad. Organic carbon was determined by rapid titration method[23] Total nitrogen was determined by using Kjeldahl digestion method.[24] Available nitrogen was determined by Alkaline Permanganate method. Potash was estimated by Flame Photometer method[25]. Phosphate was determined by Olsen's method 1954 (0.5M. $NaHCO_3$, pH 8.5) with the help of colorimeter. Cation exchange capacity was determined by using neutral normal ammonium acetate solution.[26]

Experimental: After systematic survey factorial experiment was conducted to study the effect of compost (organic matter) on the uptake of cadmium by Spinach (*Spinaceaoleracea* L.) The experiment was replicated thrice with nine treatments and conducted in completely factorial randomized block design (factorial RBD). After 24 hr of the treatment seeds were sown. Soil moisture was maintained by irrigating the crops at interval of 5-6 days. Test crop was harvested at 45 days after sowing (DAS). Spinach was grown successively in the 27 pots (each of $1m^2$ in area). The treatments of Cd × compost relationship consisted of 0, 10 and 20 t ha^{-1} compost with 0, 5 and 10 mg kg^{-1} Cd. The source of Cd and compost were $CdCl_2$, and compost respectively.

Plant analysis: Plant samples were collected along with roots, washed with deionized water and then dried in an oven at (60ºC). Dried plant materials were ground and digested in acids for metal analysis. Heavy metals in plants were determined by tri-acid mixture (HNO_3, conc. H_2SO_4 and $HClO_4$ in 5:1:1 ratio).[27] Heavy metals in soil and plant were determined by Inductively Coupled Plasma Spectrometry (ICP-AES; Model- LABTEM, Perkin Elmer, Inc.) at Central Environment Pollution Control Lab, Indian Farmer Fertilizer Cooperative (IFFCO), Ltd., Phulpur Unit, Ghiya Nagar, Phulpur, Allahabad.

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 (SE) is given by $SE = \sqrt{\frac{2V_E}{n}}$, where, V_E is the variance due to the error, n is the number of replications, and the critical difference (CD) is given by CD = $SE_{diff.} \times t_{5\%}$ ($t_{5\%}$= 2.042 at DF_{error}= 30 was observed) and standard deviation (Syx) were determined in accordance with.[28]

RESULTS AND DISCUSSION

Effect of Cd × compost interaction on dry biomass yield of Spinach: The data (Table 1) indicated highly significant effects of Cd, compost and Cd × compost interaction on influencing the dry biomass content of Spinach, which decreased as the doses of Cd increased up to 10 mg kg^{-1}. The application of 20 t ha^{-1} compost significantly increased dry biomass content of Spinach by 13.1%,[29] whereas, compost @ 20 t ha^{-1} treatment in the Cd 10 mg kg^{-1} added plots boosted the dry biomass yield by 5.4% over the control (fig.1) has also reported similar findings[30]. Added single dose of Cd 10 mg kg^{-1} (T_7) maximum reduced the dry biomass yield of Spinach by 27.8% over the control, have also reported similar findings[31].

Table: 1. Effect of Cd × compost interaction on dry biomass yield of Spinach (g/plots)

Treatments	Dry biomass yield (g/plots)
T_1	367
T_2	380
T_3	415
T_4	323
T_5	372
T_6	400
T_7	265
T_8	355
T_9	387
S.E.	**5.51**
C.D.	**11.68**

Effect of Cd × compost interaction on Cd concentration in shoot and root of Spinach: The data (Table 2 and 3) indicated highly significant effect of Cd, compost and interaction of Cd × compost on cadmium accumulation by root and shoot both parts of plants. Application of 10 mg kg^{-1} Cd (T_7) drastically promoted the accumulation of Cd by 3.0-1.7 folds shoot and root over the control, respectively. The application of 10 mg kg^{-1} Cd registered the highest accumulation of Cd (1.45 mg kg^{-1} and 2.43 mg kg^{-1} in root and shoot, respectively) in Spinach (Fig. 2&3). The study further indicated that the toxicity of Cd in combined application of compost @ 20 t ha^{-1} along with varying doses of Cd (0, 5 and 10 mg kg^{-1}) decreased significantly. Application of Cd 10 mg kg^{-1} + 20 t ha^{-1} compost (T_9) increases the accumulation 1.1 fold (mean 0.95 mg kg^{-1}) and 1.5 fold (mean 1.20 mg kg^{-1}) of Cd in the root and shoot of plants, over the control, respectively, have also reported almost similar findings[32-33]. The uptake of metals from the soil to plant depends on different factors such as their soluble salt content in it, soil pH, and plant growth stages types of species, fertilizer and soil.[34-35]

Table 2: Effect of Cd × compost interaction on Cd concentration in shoot and root of Spinach (mg kg^{-1})

Treatments	Cd concentration (in mg kg^{-1})	
	Shoot	Root
T_1	0.80	0.85
T_2	0.76	0.80
T_3	0.70	0.72
T_4	1.93	1.36
T_5	1.40	1.00
T_6	0.88	0.92
T_7	2.43	1.45
T_8	1.55	1.10
T_9	1.20	0.95
SE	**0.05**	**0.08**
COD	**0.10**	**0.17**

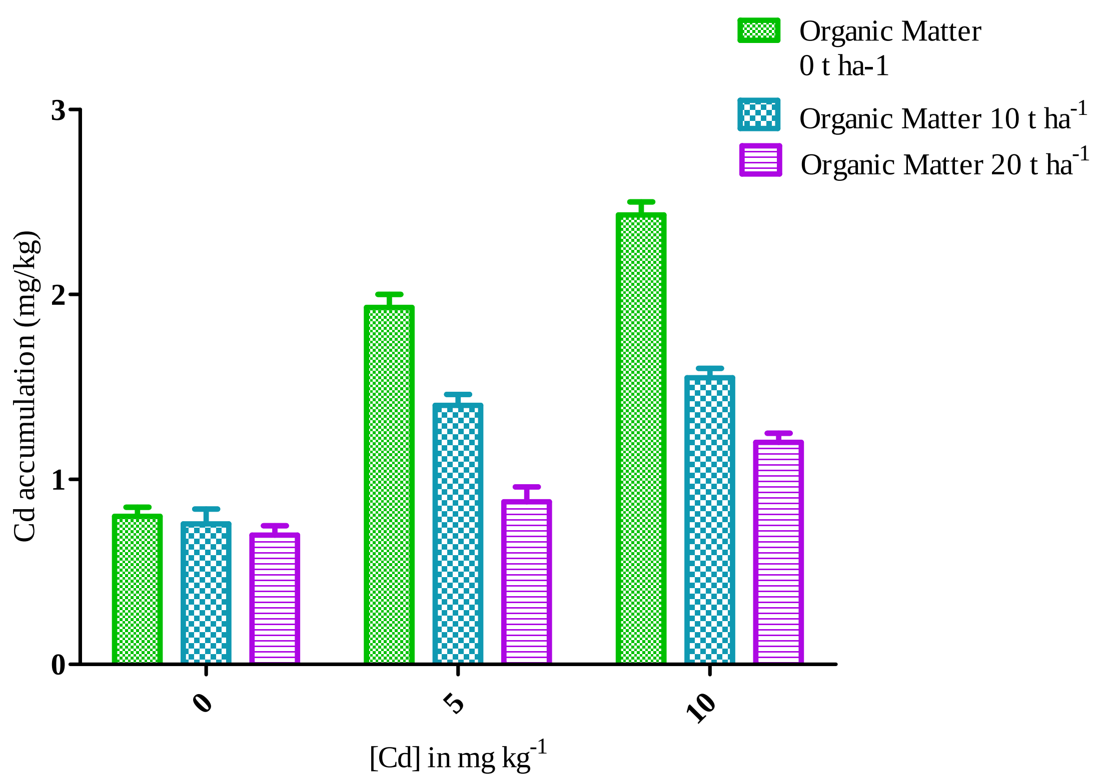

Figure 1: Effect of Cd × Compost interaction on Cd concentration in shoot of Spinach (mg kg^{-1})

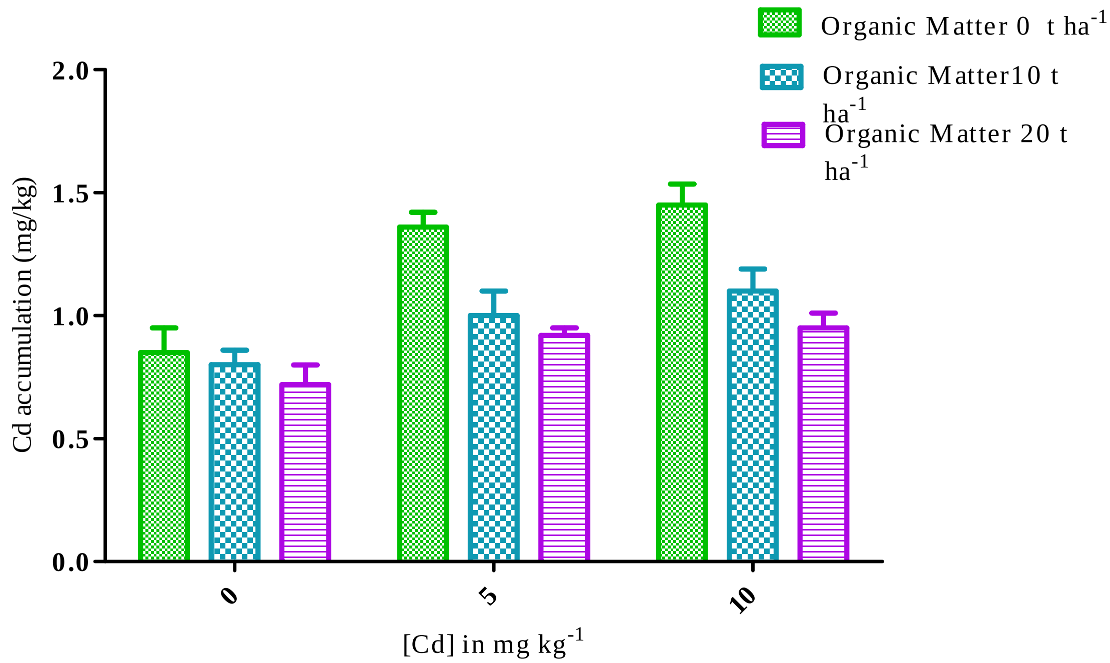

Figure 2: Effect of Cd × Compost interaction on Cd concentration in root of Spinach (mg kg^{-1})

CONCLUSION

Organic matter treated plots registered the highest dry biomass yield of Spinach (*Spinaceaoleracea* L.) by 36.5%. Application of organic matter @ 20 t ha^{-1} was found most effective in boosting the dry biomass content of crop. Cd @ 10 mg kg^{-1} influenced the dry biomass content diminutively, which was recorded 27.8 % decrease over the control plots in Spinach. Application of Cd 10 mg kg^{-1} increased the highest accumulation of Cd in shoot of Spinach by 5.7 folds. Spinach can be an useful crop for Phytoremediation of cadmium-contaminated soils. Many agricultural lands in our country are often polluted by industrial wastewater. Therefore cadmium content in the Spinach leaves should be monitored regularly. Efforts must be taken for bioremediation of cadmium in such soils. Spinach definitely could be such a bioremediation measure.

The higher accumulation of heavy metals in plants led to reduced photosynthetic rate and chlorophyll pigments, stunted growth, and lowering of yield. The contents of Cd and Pb in different tissues of vegetables changed with various ways of treatments. The entry of heavy metals to the food chain through soil-plant rhizosphere process and the possible influence to human health needs to be explored. Being an important part of the human diet, vegetable consumption by human being has got an increasing trend. Metal accumulation in vegetables, therefore, may pose a direct threat to the human health.

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