Threshold toxic limits of Cd for leafy vegetables raised on a mollisol amended with varying levels of farmyard manure

Deepali Joshi [A], Prakash Chandra Srivastava [B] and Prashant Srivastava [C]

[A]Department of Soil Science, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263145, India.
[B]Department of Soil Science, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263145, India, Email pcsriv@yahoo.com
[C]Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, University of South Australia, Mawson Lakes, SA 5095, Australia, Email prashant.srivastava@crccare.com

Abstract
Green house experiments were conducted during 2008-09 to evaluate the threshold toxic limits of Cd in leafy vegetables grown on a Mollisol receiving varying levels of farmyard manure (FYM). The treatments involved factorial combinations of three levels of FYM (0, 2.23 and 4.46 g/kg soil), seven levels of Cd (0, 5, 10, 25, 50, 100 and 150 mg Cd/kg soil) which were imposed on three plant species (amaranthus, Fenugreek and Buckwheat). Amaranthus was most susceptible to the toxicity of Cd as compared to fenugreek and buck wheat. The threshold toxic limits of Cd in plant tissue for 10 percent reduction in the relative yields of leafy vegetables at 0, 2.23 and 4.46 g FYM/kg soil were 7.3, 29.5 and 10.3 mg Cd/kg dry matter in amaranthus, 2.5, 3.6 and 4.9 mg Cd/kg dry matter in fenugreek and 6.0, 21.0, 15.3 mg Cd/kg dry matter in buckwheat, respectively. The threshold toxic limits of 0.1 *N* HCl extractable Cd in soil for 10 percent reduction in the relative yields of leafy vegetables at 0, 2.23 and 4.46 g FYM/kg soil levels were 1.4, 4.0 and 2.0 for amaranthus, 3.0, 6.7 and 20.5 mg Cd/kg soil for fenugreek and 2.8, 14.5 and 14.6 mg Cd/kg soil for buck wheat, respectively. The threshold toxic limits of 0.005 *M* DTPA (pH 7.3) extractable Cd in soil for 10 percent reduction in the relative yields of leafy vegetables at 0, 2.23 and 4.46 g FYM/kg soil levels were 1.3, 3.3 and 1.9 for amaranthus, 1.8, 3.4 and 9.0 mg Cd/kg soil for fenugreek and 1.6, 11.5 and 7.9 mg Cd/kg soil for buck wheat, respectively.

Key Words
Cadmium, farmyard manure, leafy vegetables, Mollisol, soil extractants, threshold toxic limits.

Introduction
Leafy vegetables are among the crop species that are most vulnerable to heavy metal pollution. Leafy vegetables accumulate higher amount of heavy metal like Cd due to their intense vegetative growth. Cadmium contaminated vegetables grown in wastewater irrigated soils may pose public health hazards. The increase in the accumulation of Cd in soils leads to increase in the uptake of metals, thereby, creating complex situation in soil-plant-animal-human system. The present investigation was carried out with the objective of evaluating the toxic concentrations of Cd for amaranthus (*Amaranthus spp.*), fenugreek (*Trigonalia foenum*) and buckwheat (*Crotalaria retusa*) grown in a mollisol receiving varying levels of farmyard manure.

Methods
Greenhouse experiments
Greenhouse experiments were conducted using a surface (0-15 cm) Mollisol having sandy loam texture, 7.05 pH and 0.128 dS/m electrical conductance in 1:2 soil water suspension, 11.1 g/kg organic C and 0.16 mg/kg DTPA extractable Cd/kg soil. The treatments imposed in triplicate to potted soil (2.5 kg/pot) were a factorial combination of three levels of FYM (0, 2.23 and 4.46 g/kg soil) and seven levels of Cd (0, 5, 10, 25, 50, 100 and 150 mg Cd/kg soil). The content of total Cd in FYM was 2.4 mg Cd/kg. Healthy Seeds of amaranthus (*Amaranthus spp.*), fenugreek (*Trigonalia foenum*) and buckwheat (*Crotalaria retusa*) were sown and raised near field capacity moisture regime. After 35 d growth, plants were harvested close to soil level and washed thoroughly in tap water, 0.1 *N* HCl and finally in distilled water. Plants were dried in an electric oven at 60˚C and weighed to record dry matter yields. Percent relative dry matter yields were calculated for different treatments as:
Relative yield (%) = (Dry matter yield at a given level of Cd / Dry matter yield at 0 mg Cd/kgsoil) × 100

Soil extraction
After crop harvest, the soil samples under different treatments were extracted for 0.005 *M* DTPA (pH 7.3) extractable Cd (Korcak and Fanning, 1978) and 0.1*M* HCl method (Misra and Pande, 1974). Finely ground plant sample (1 g) was digested in di-acid (HNO_3: $HClO_4$, 3:1 v/v). Soil and plant extracts were analysed for Cd by atomic absorption spectrophotometry.

Critical toxic limits of Cd in mollisol and plants
A method proposed by Bingham *et al.* (1975) was employed to calculate the critical toxic concentration of Cd in soil and plants. Percent relative dry matter yields were plotted against extractable content of Cd in soil or content of Cd in plant tissues. Critical toxic limits of Cd in soil and plants were determined for 10 percent reduction in dry matter yield.

Results
Cadmium levels significantly influenced the dry matter yields of all the three tested leafy vegetables (Table 1). In comparison to control (0 mg Cd/kg soil) decreased dry matter yields were observed at 5 to 150 mg Cd/kg soil for amaranthus, at 50 to 150 mg Cd/kg soil for fenugreek and at 25 to 150 mg Cd/kg soil for buckwheat. In general, FYM application did not influence the dry matter yields of amaranthus and fenugreek however, in the case of buckwheat higher level of FYM slightly decreased the dry matter yield in comparison to no application of FYM. The interaction effect of Cd and FYM levels influenced the dry matter yield of only amaranthus significantly. In general, at 0 and 4.46 g FYM/kg soil all the levels of Cd (5 to 150 mg Cd./kg soil) caused a decrease in dry matter yield of amaranthus. However at 2.23 g FYM/kg soil levels, only Cd levels from 10 to 150 mg/kg soil decreased the dry matter yield of amaranthus, significantly in comparison to control.

Table 2. Effect of cadmium and FYM application on dry matter yield (g/pot) of leafy vegetables.

Cd levels	FYM levels (g/kg soil)			
(mg/kg soil)	0	2.23	4.46	Mean
	A. Amaranthus			
0	9.49	6.07	6.38	7.31
5	4.07	5.62	4.12	4.60
10	5.65	3.03	2.74	3.81
25	2.06	2.69	2.61	2.45
50	1.20	1.08	1.46	1.25
100	0.55	0.70	0.41	0.55
150	0.29	0.30	0.21	0.26
Mean	3.33	2.78	2.56	2.89
Effect	FYM levels	Cd levels	FYM × Cd levels	
CD (P≤0.05)	NS	1.00	1.73	
	B. Fenugreek			
0	1.28	1.18	0.91	1.12
5	1.11	1.15	1.26	1.17
10	1.09	0.99	0.97	1.02
25	1.04	0.87	1.35	1.08
50	0.96	0.71	0.63	0.76
100	0.63	0.69	0.46	0.59
150	0.47	0.42	0.84	0.88
Mean	0.94	0.86	0.84	0.88
Effect	FYM levels	Cd levels	FYM × Cd levels	
CD (P≤0.05)	NS	0.20	NS	
	C. Buckwheat			
0	2.70	2.30	2.10	2.37
5	2.30	2.83	1.94	2.35
10	2.20	2.25	1.95	2.13
25	1.90	2.10	1.50	1.83
50	1.60	1.53	1.33	1.48
100	1.13	1.35	1.10	1.19
150	0.93	0.75	0.66	0.78
Mean	1.82	1.87	1.51	1.78
Effect	FYM levels	Cd levels	FYM × Cd levels	
CD (P≤0.05)	0.23	0.36	NS	

As shown in Figure 1, addition of increasing levels of Cd significantly increased the concentration of Cd in leafy vegetables, the magnitude of increase was highest in amaranthus followed by buckwheat and fenugreek. As regards the main effects of FYM levels, application of 4.46 g FYM/kg soil increased the Cd concentration significantly only in amaranthus over no application of FYM (0 g FYM/kg soil). The interaction effect of Cd and FYM levels also influenced the concentration of Cd in leafy vegetables significantly.

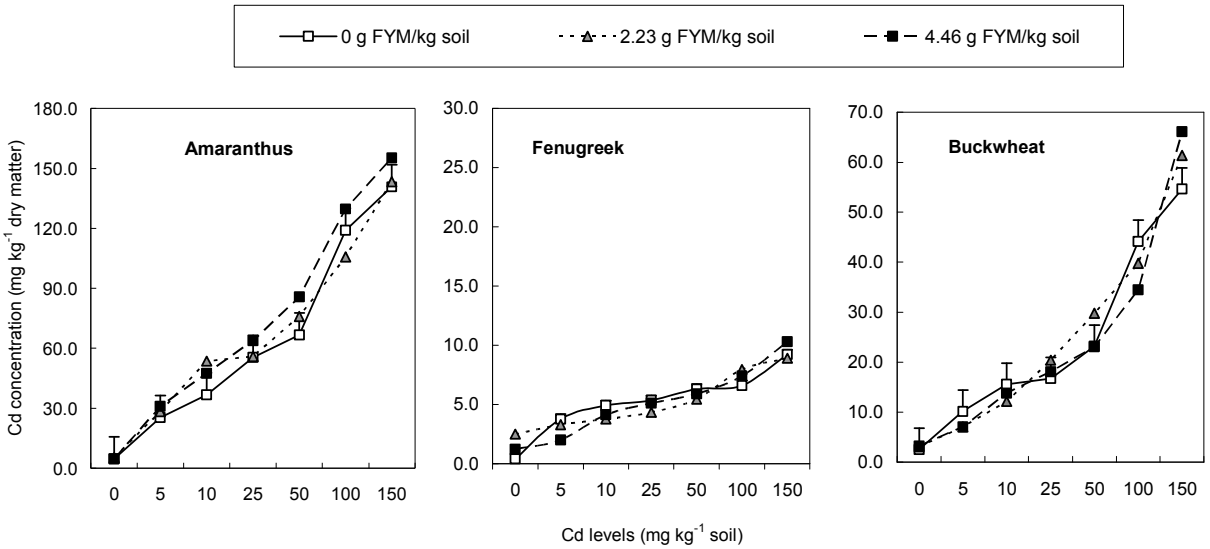

Figure1. Effect of different levels of Cd on Cd concentrations (mg/kg dry matter) in leafy vegetables raised on a mollisol fertilized with varying levels 0f FYM. The vertical bars indicate critical difference at $P \leq 0.05$.

The threshold toxic limits of Cd for 10 percent reduction in the yields of leafy vegetables at 0, 2.23 and 4.46 g FYM/kg soil were 7.3, 29.5 and 10.3 mg Cd/kg dry matter in amaranthus, 2.5, 3.6 and 4.9 mg Cd/kg dry matter in fenugreek, and 6.0, 21.0, 15.3 mg Cd/kg dry matter in buckwheat, respectively (Table 2), respectively. In general, application of FYM led to relatively higher threshold toxic limits of Cd in plant tissue in comparison to no application of FYM. The effect could be ascribed to the fact that the magnitude of reduction in dry matter due to Cd levels was lower under FYM treatments than under no application of FYM.

Table 3. Threshold limits of Cd in plants for 10 percent reduction in relative yields.

FYM level (g/kg soil)	Cd (mg/kg dry matter)		
	Amaranthus	Fenugreek	Buckwheat
0	7.3	2.5	6.0
2.23	29.5	3.6	21.0
4.46	10.3	4.9	15.3

The threshold toxic limits of 0.1 *N* HCl extractable Cd in soil for 10 percent reduction in the relative yields of leafy vegetables at 0, 2.23 and 4.46 g FYM/kg soil levels were 1.4, 4.0 and 2.0 for amaranthus, 3.0, 6.7 and 20.5 mg Cd/kg soil for fenugreek, and 2.8, 14.5 and 14.6 mg Cd/kg soil for buck wheat, respectively (Table 3). The threshold toxic limits of 0.005 *M* DTPA (pH 7.3) extractable Cd in soil for 10 percent reduction in the relative yields of leafy vegetables at 0, 2.23 and 4.46 g FYM/kg soil levels were 1.3, 3.3 and 1.9 for amaranthus, 1.8, 3.4 and 9.0 mg Cd/kg soil for fenugreek, and 1.6, 11.5 and 7.9 mg Cd/kg soil for buck wheat, respectively.

Table 4. Threshold limits of extractable Cd in soil for 10 percent reduction in relative yields.

Soil Extractant	FYM level	Cd (mg/kg soil)		
	(g/kg soil)	Amaranthus	Fenugreek	Buckwheat
0.1 *N* HCl	0	1.4	3.0	2.8
	2.23	4.0	6.7	14.5
	4.46	2.0	20.5	14.6
0.005 *M* DTPA (pH 7.3)	0	1.3	1.8	1.6
	2.23	3.3	3.4	11.5
	4.46	1.9	9.0	7.9

Both, DTPA (pH 7.3) and 0.1 *N* HCl extractable Cd had significant ($p \leq 0.01$) positive correlation with Cd concentration in plant tissue of all the three leafy vegetables (Table 4). For amaranthus and buckwheat, 0.1 *N* HCl had higher r values with Cd concentration in the plant tissue as compared to DTPA extractable Cd. However, in the case of fenugreek slightly higher value was obtained with DTPA (pH 7.3) extractant.

Table 5. Relationship between extractable soil Cd and concentration and uptake of Cd by different leafy vegetables.

Crop	Soil Extractant	Cd concentration	Cd uptake
Amaranthus spp	DTPA	0.916**	0.317
	0.1 *N* HCl	0.957**	0.472*
Fenugreek	DTPA	0.928**	0.375
	0.1 *N* HCl	0.923**	0.210
Buckwheat	DTPA	0.922**	0.833**
	0.1 *N* HCl	0.963**	0.820**

**significant at $P \leq 0.01$; *significant at $P \leq 0.05$

The uptake of Cd by amaranthus and buckwheat showed a significant positive correlation with 0.1 *N* HCl extractable Cd. The uptake of Cd by buckwheat also showed a significant positive correlation with DTPA (pH 7.3) extractable Cd.

Conclusion

Increasing levels of Cd significantly reduced the dry matter production of leafy vegetables. Among leafy vegetables, the concentration of Cd was the highest in amaranthus followed by buckwheat and fenugreek. Application of FYM increased the threshold toxic limits of Cd in the tissues of leafy vegetables and also in terms of 0.1 *N* HCl or 0.005 *M* DTPA (pH = 7.3) extractable Cd in Mollisols.

References

Bingham FT, Page AL, Mahler RJ, Ganje TJ (1975) Growth and cadmium accumulation of plants grown on a soil treated with a cadmium enriched sewage sludge. *Journal of Environmental Quality* **4**, 207-211.

Korcak RF, Fanning DS (1978) Extractability of cadmium, copper, nickel and zinc by double acid versus DTPA and plant content at excessive soil levels. *Journal of Environmental Quality* **7**, 506-512.

Misra SG, Pande P (1974) Evaluation of suitable extractant for available nickel in soils. *Plant and Soil* **41**, 697-700.