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Patel Vimal N
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, Anand Agricultural University, Anand, Gujarat, India

Chaudhary Kamalesh V
M.Sc. Student, Department of Soil Science and Agricultural Chemistry, Anand Agricultural University, Anand, Gujarat, India

Patel Dipak H
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, Anand Agricultural University, Anand, Gujarat, India

Gohil Naresh B
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, Anand Agricultural University, Anand, Gujarat, India

Correspondence
Patel Vimal N
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, Anand Agricultural University, Anand, Gujarat, India

Effect of farmyard manure for phytostabilization of Cd through forage sorghum and forage maize

Patel Vimal N, Chaudhary Kamalesh V, Patel Dipak H and Gohil Naresh B

Abstract
A pot trial was undertaken in order to generate location specific information on “Effect of farmyard manure for phytostabilization of Cd through forage sorghum and forage maize” the study was conducted during *summer*, 2014 at pot house, modern laboratory, Micronutrient Research Project (I.C.A.R), Anand Agricultural University, Anand. The pot experiment was laid out in completely randomized design (factorial) with three repitation. Total twenty treatments comprisingof five doses of Cd (0, 10, 20, 40 and 80 ppm) and two levels of FYM (0 and 20 t ha^{-1}) were tested in forage maize and forage sorghum crops. Among different treatment combinations $Cd_{80}F_0$ recorded maximum values of Cd in root and shoot of maize and sorghum crop, but the concentration of Cd was reduced due to FYM application @ 20 t ha^{-1} at each level of applied cadmium. The reduction in cadmium content due to FYM @ 20 t ha^{-1} was 23.8 and 37.6 per cent under shoot of maize and sorghum at the highest level of applied cadmium (Cd_{80}) respectively, in case of root reduction was 18.3 and 24.8 per cent due to FYM application @ 20 t ha^{-1} under maize and sorghum, respectively. Along with application of FYM @20 t ha^{-1}increased EC and OC while decreased pH value in the soil and it was significantly reduced the availability of Cd in the soil and significantly increased all the major nutrients viz., N, P_20_5, K_20 and micronutrients viz., DTPA-Mn, Zn, Cu and Fe status in soil after harvest of both the crops over no FYM application.

Keywords: Cadmium, FYM, maize, sorghum, Phytostabilization

1. Introduction

Owing to the continuous soil enrich with Cd from agricultural activities and the potential risks paused by these metal as well as reduce the impact of heavy metals and human health by preventing their transfer to the food chain, therefore urgent need to reduce the metal transfer to agricultural plants (Anand Prakash Singh, 2011) [1]. Metals in contaminated soils are present as chemical forms with different mobility and availability to human and ecological receptors. As a consequence there has been great concern for *in-situ* remedial strategies that render metals less mobile to minimize the environmental and human risks therefore it is advantageous to develop cost effective remediation strategies. Phytostabilization is the cost effective phytoremediation strategies. FYM is the source ofprimary, secondary and micronutrient to the plant growth. It is a constant source of energy for heterotrophic microorganisms, help in increasing the availability of nutrient quality and quality of crop produce. Farm yard manure (FYM) improves the crop production (Kaihura *et al.* 1999) [2] as well as improves soil physical properties (Chen *et al*. 1996) [3] and can be used to reduce heavy metal hazards in plants (Yassen *et al.* 2007) [4]. Organic matter with respective groups such as hydroxyl, phenolic and carboxyl effectively controls the adsorption and complexation of heavy metal and the activity of metal in the soil (Lee *et al.* 2004; Mahmood, 2010) [5].

2. Materials and Methods

The study was conducted during *summer*, 2014 at pot house, modern laboratory, Micronutrient Research Project (I.C.A.R), Anand Agricultural University, Anand. The pot experiment was laid out in completely randomized design (factorial) with three repitation. The texture of the soil is loamy sand. The soil was loamy sand in texture, neutral in reaction (pH 7.9), low in organic carbon (0.33 per cent), Total twenty treatments comprising of five doses of Cd (0, 10, 20, 40 and 80 ppm) and two levels of FYM (0 and 20 t ha^{-1}) were tested in forage maize and forage sorghum crops.

3. Results and Discussion

Effect of different treatments on Cd content in shoot & root of maize and sorghum at 30 and 60 DAS

3.1 Effect of FYM and Cd on Cd content

The data on Cd content in maize (C_1) and sorghum (C_2) crops as influenced by FYM and Cd applications at 30 and 60 DAS are presented in Table 1.

3.1.1 Effect of Crops

The maize (C_1) and sorghum (C_2) crops had significant effect on Cd content in plant (Table 1). The results revealed that at 30 DAS Cd content in shoot and root was significantly higher (17.02 and 13.51 per cent) in sorghum crop (C_2) as compared to maize crop (C_1) and at 60 DAS Cd content in shoot and root was significantly higher (18.19 and 11.40 per cent) in sorghum crop (C_2) as compared to maize crop (C_1). It might be due to that with increased Cd concentration with increasing levels of Cd application is primarily due to increased availability of Cd in soil (Dahiya *et al.*1987 and Singh *et al.* 1994) [6, 7].

3.1.2 Effect of FYM

Increasing levels of FYM produced significant effect on Cd content (Table 4.6). The results showed that at 30 DAS Cd content was significantly reduced to 22.99 per cent in shoot and 22.67 per cent in root. And at 60 DAS Cd content was significantly reduced from 21.09 per cent in shoot and 21.62 per cent in root when FYM levels raised from 0 to 20 t ha^{-1}. It might be due to phytostabilization of Cd by FYM and the addition of FYM to soil can reduce the heavy metal bio availability by changing them from bio available forms to the fractions associated with organic matter or metal oxides or carbonates the organic C present in the FYM is responsible for the release of negatively charged ions that attract the positively charged Cd and consequently results into more retention Cd in the soil with lower availability to the plant (Abbott *et al*. 2001) [8]. The same has been confirmed by the findings of Shaha *et al.* (2012) [9]; Alamgir *et al.* (2011) [10] and Singh *et al.* (2011) [11].

3.1.3 Effect of Cd levels

A perusal of data (Table 1) showed varying levels of Cd significantly increased the Cd content in shoot and root of the crop. At 30 DAS the application of 80 ppm Cd (Cd_{80}) registered higher Cd content in shoot (14.39 ppm) and root (15.61 ppm) and at 60 DAS the application of 80 ppm Cd (Cd_{80}) recorded higher Cd content in shoot (12.55 ppm) and root (12.99 ppm) as compared to rest of the treatments. An increasing trend in Cd content was observed with increasing levels of Cd application.

The root of maize and sorghum plant contained significantly more Cd than shoot component. The soluble root exudates and root induced changes in the rhizosphere are expected to influence the available Cd content in soil solution. Marschner, (1986) [12] documented that change in rhizosphere pH due to exudates influenced the Cd availability to the roots. The poor translocation of absorbed Cd by root to the above ground plant part was also reported by Wanger *et al.* (1988) [13] in tobacco, Buckley *et al.* (1997) [14] in durum wheat and Ghani (2010) [15] in maize.

Table 1: Effect of different treatments on Cd content (ppm) in shoot and root of maize and sorghum at 30 and 60 DAS

30 DAS			60 DAS	
Treatments	**Shoot**	**Root**	**Shoot**	**Root**
Type of crops (C)				
C1: Maize	5.41	6.27	4.54	5.28
C_2: Sorghum	6.52	7.25	5.55	5.96
S.Em. ±	0.03	0.06	0.04	0.03
C.D. at 5%	0.09	0.18	0.11	0.10
Levels of FYM (F)				
F_0: 0 t ha^{-1}	6.74	7.63	5.64	6.18
F_1: 20 t ha^{-1}	5.19	5.90	4.45	5.06
S. Em. ±	0.03	0.06	0.04	0.03
CD at 5%	0.09	0.18	0.11	0.10
Levels of Cd (Cd)				
Cd_0: 0 ppm	0.12	0.15	0.09	0.12
Cd_{10}:10 ppm	2.39	2.88	1.73	2.38
Cd_{20}:20 ppm	4.32	5.37	3.30	4.46
Cd_{40}:40 ppm	8.60	9.79	7.56	8.15
Cd_{80}:80 ppm	14.39	15.61	12.55	12.99
S. Em. ±	0.05	0.10	0.06	0.05
C.D. at 5%	0.15	0.18	0.17	0.15
Significant Interactions	C × F C × Cd F × Cd	C × F C × Cd F × Cd	C × F C × Cd F × Cd C × CD × F	C × F C × Cd F × Cd C × CD × F
C.V. %	3.002	5.16	4.14	3.24

3.1.4 Interaction effect

At 30 DAS the possible interactions C × F, C × Cd, F × Cd and were found to be significant for Cd content in shoot and root of maize and sorghum crop and at 60 DAS. All the possible interactions C × F, C × Cd, F × Cd and C × Cd × F were found to be significant for Cd content in shoot and root of maize and sorghum crop and the relative data are presented in Table 1a, 1b, 1c and 1d.

3.1.4.1 Effect of C × F interaction

The Cd content significantly decreased with application of FYM than no FYM in irrespective of crop at 30 and 60 DAS (Table 1a).

The data in Table 4.6a on the interaction effect between Crops and FYM levels on Cd content revealed that at 30 DAS the treatment combination C_2F_0 recorded significantly highest Cd content (7.32 ppm) in shoot and 8.23 ppm in root and the lowest Cd content (4.78 ppm) recorded in C_1F_1 treatment in shoot and 5.67 ppm in root. The per cent decrease in Cd content of maize crop (C_1) is 20.72 and 17.46 and in sorghum crop (C_2) it is 21.85 and 23.69 in shoot and root respectively with application of FYM @20 t ha^{-1}.

At 60 DAS the treatment combination C_2F_0 recorded significantly the highest Cd content (4.95 ppm) in shoot and (6.57 ppm) in root and the lowest Cd content recorded in C_1F_1 treatment (3.74 ppm) in shoot and (4.77 ppm) in root. The per cent decrease in Cd content of maize crop is 13.82 and 17.75 and in sorghum crop it is 18.18 and 18.56 in shoot and root respectively with application of FYM @20 t ha^{-1}.

Table 1a: Interaction effect of Crops and FYM (C × F) on Cd (ppm) content in shoot and root of maize and sorghum at 60 DAS

Shoot				
	30 DAS		**60 DAS**	
FYM levels Type of Crops	F_0	F_1	F_0	F_1
C_1	6.03	4.78	4.34	3.74
C_2	7.32	5.72	4.95	4.05
C × F	S. Em. ± C.D. at 5% 0.05 0.13		S. Em. ± C.D. at 5% 0.06 0.18	
Root				
C_1	6.87	5.67	5.80	4.77
C_2	8.23	6.28	6.57	5.35
C × F	S. Em. ± 0.09	C.D. at 5% 0.26	S. Em. ± 0.05	C.D. at 5% 0.13

3.1.4.2 Effect of C × Cd interaction

The statistical analysis of C × Cdinteractions with respect to Cd content in shoot and root of maize and sorghum revealed that Cd content in shoot and root was significantly higher in sorghum crop (C_2) than maize crop (C_1) under all levels of Cd addition to the soil at 30 & 60 DAS respectively (Table 1b). Among the all treatment combination at 30 DAS significantly highest (15.40 ppm) Cd content in shoot and (16.44 ppm) in root was found under the C_2Cd_{80} treatment.

Table 1_b: Interaction effect of crops and cadmium (C × Cd) on Cd (ppm) content in shoot and root of maize and sorghum at 30 and 60 DAS

Cd levels Type of crops	**30 DAS**				
	Cd_0	Cd_{10}	Cd_{20}	Cd_{40}	Cd_{80}
Shoot					
C_1	0.11	2.22	4.04	7.29	13.39
C_2	0.13	2.55	4.61	9.92	15.40
C × Cd	S. Em. ± 0.07			C.D. at 5% 0.21	
Root					
C_1	0.14	2.57	4.91	8.95	14.78
C_2	0.16	3.19	5.84	10.63	16.44
C × Cd	S. Em. ± 0.14			C.D. at 5% 0.41	
60 DAS					
Shoot					
C_1	0.08	1.52	2.92	6.30	11.88
C_2	0.10	1.94	3.68	8.82	13.42
C × Cd	S. Em. ± 0.10			C.D. at 5% 0.28	
Root					
C_1	0.12	2.18	4.09	7.62	12.41
C_2	0.13	2.58	4.83	8.67	13.57
C × Cd	S. Em. ± 0.07			C.D. at 5% 0.21	

At 60 DAS significantly highest (13.42 ppm) in shoot and (13.57 ppm) in root Cd content was found under the C_2Cd_{80} treatment With increasing Cd levels, the Cd content increased significantly in shoot and root and the Cd_{80} level showed the highest Cd content compared to control (Cd_0).

3.1.4.3 Effect of F × Cd interaction

Data pertaining to Cd content in shoot and root of maize and sorghum crop as influenced by F × Cd interaction showed that Cd content in shoot and root was significantly higher without FYM (F_0) application in both crops than FYM (F_1) treated one, under all levels of Cd addition at 30 and 60 DAS respectively (Table 1c). Increasing trend in Cd content was found in shoot and root with the increasing levels of Cd but FYM application reduced Cd content significantly at all Cd levels. It is graphically illustrated in fig. 1, 2, 3 and 4.

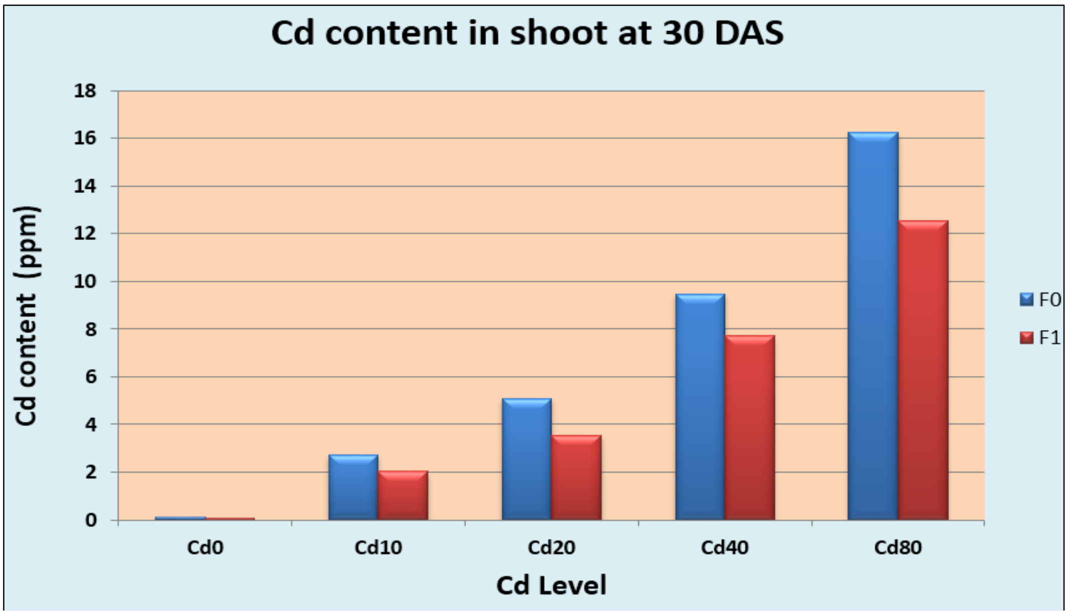

Fig 1: Effect of FYM and cadmium (F × Cd) on Cd (ppm) content in shoot of maize and sorghum at 30 DAS

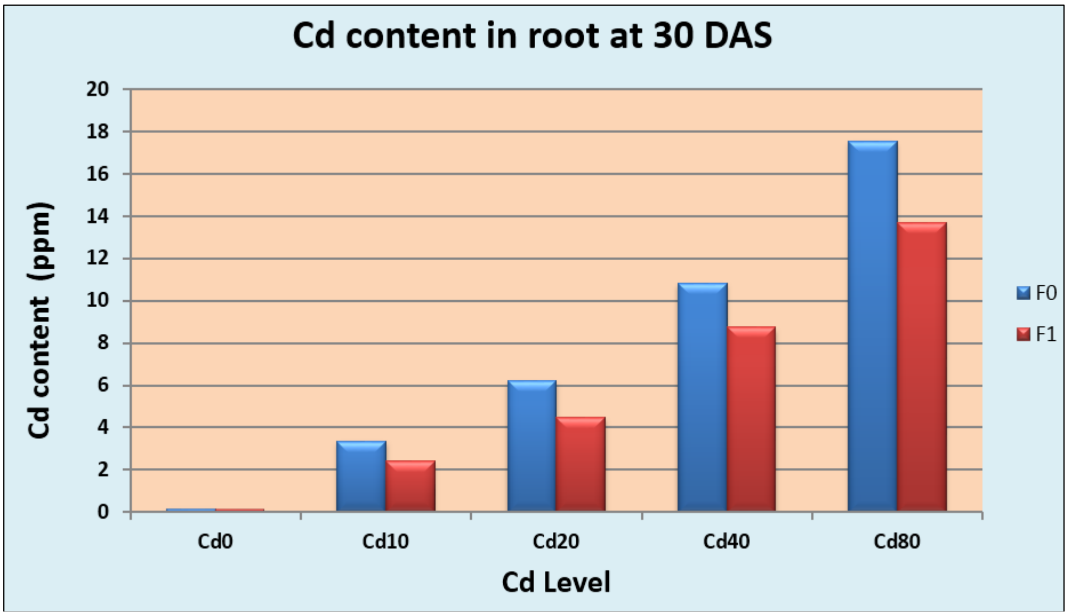

Fig 2: Effect of FYM and cadmium (F × Cd) on Cd (ppm) content in root of maize and sorghum at 30 DAS

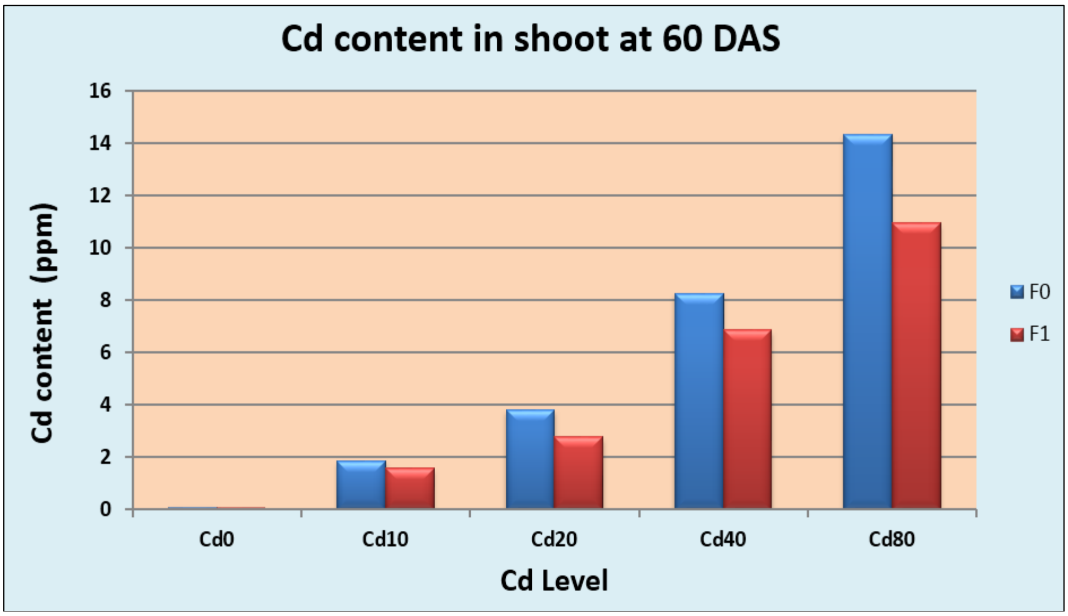

Fig 3: Effect of FYM and cadmium (F × Cd) on Cd (ppm) content in shoot of maize and sorghum at 60 DAS

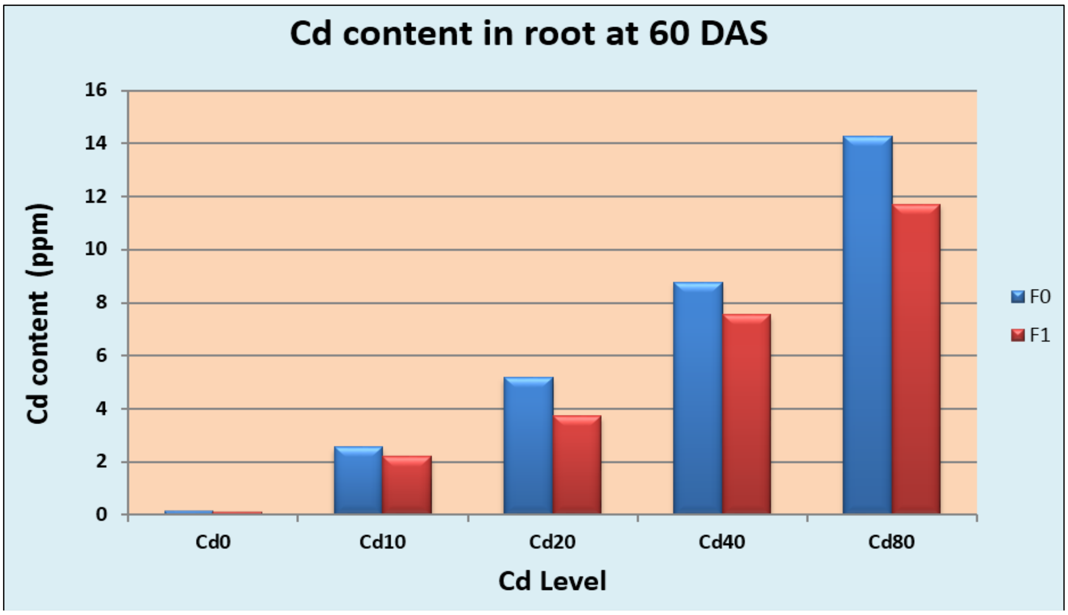

Fig 4: Effect of FYM and cadmium (F × Cd) on Cd (ppm) content in root of maize and sorghum at 60 DAS

3.1.4.4 Effect of C × Cd × F interaction

As regard the interaction effect of crop, FYM and Cd levels, the content of Cd in shoot and root was found to increase with increasing rates of Cd application with or without FYM addition in both the crops (Table 1d). The highest Cd content in shoot and root were recorded under $C_2Cd_{80}F_0$ (15.55 and 15.07 ppm, respectively) which further decreased significantly when $C_2Cd_{80}F_1$ treatment combination was tried (11.03 and 12.08 ppm respectively). These results corroborate with the findings reported by Ahmed *et al*. (2011) [16].

Table 1c: Interaction effect of FYM and cadmium (F × Cd) on Cd (ppm) content in shoot and root of maize and sorghum at 30 and 60 DAS

Cd levels FYM levels	30 DAS				
	Cd_0	Cd_{10}	Cd_{20}	Cd_{40}	Cd_{80}
Shoot					
F_0	0.14	2.74	5.10	9.48	16.23
F_1	0.10	2.03	3.55	7.72	12.56
F × Cd	S. Em. ± 0.07			C.D. at 5% 0.21	
Root					
F_0	0.17	3.35	6.24	10.83	17.54
F_1	0.13	2.41	4.50	8.75	13.68
F × Cd	S. Em. ± 0.14			C.D. at 5% 0.41	
60 DAS					
Shoot					
F_0	0.10	1.87	3.83	8.26	14.35
F_1	0.08	1.59	2.77	6.86	10.96
F × Cd	S. Em. ± 0.09			C.D. at 5% 0.24	
Root					
F_0	0.15	2.57	5.18	8.75	14.26
F_1	0.10	2.19	3.73	7.54	11.72
F × Cd	S. Em. ± 0.04			C.D. at 5% 0.10	

Table 1d: Interaction effect of crop, cadmium and FYM (C × Cd × F) on Cd (ppm) content in shoot and root of maize and sorghum at 60 DAS

Type of Crops	Cd levels	FYM levels	
		F_0	F_1
		Shoot	
C_1	Cd_0	0.09	0.07
	Cd_{10}	1.71	1.33
	Cd_{20}	3.44	2.40
	Cd_{40}	6.72	5.88
	Cd_{80}	13.15	10.62
C_2	Cd_0	0.11	0.09
	Cd_{10}	2.03	1.85
	Cd_{20}	4.22	3.13
	Cd_{40}	9.80	7.84
	Cd_{80}	15.55	11.30
C × Cd × F		S. Em. ± 0.14	C.D. at 5% 0.40
		Root	
C_1	Cd_0	0.13	0.10

	Cd_{10}	2.35	2.00
	Cd_{20}	4.83	3.35
	Cd_{40}	8.24	7.01
	Cd_{80}	13.45	11.37
C_2	Cd_0	0.16	0.10
	Cd_{10}	2.79	2.38
	Cd_{20}	5.54	4.11
	Cd_{40}	9.27	8.07
	Cd_{80}	15.07	12.08
C × Cd × F		S. Em.± 0.11	C.D. at 5% 0.30

4. Status of soil after harvest of forage maize and forage sorghum

The data regarding EC, pH, OC and available nutrient status of N, P, K, Zn, Fe, Mn, Cu and Cd in soil after harvest and DTPA-Cd at 30 DAS of forage maize and forage sorghumare presented in Table 2.

4.1 Effect of crops

The analysis of soil after harvest of maize crop did not reveal significant changes in soil reaction (pH) and EC, while OC, available N, P_2O_5, K_2O, Zn, Fe, Mn and Cu contents were significantly higher in soil of after harvest of maize crop (C_1) as compared to sorghum crop (C_2).

4.2 Effect of FYM

A significant increase in EC and decrease in pH values were observed under 20 t ha^{-1} FYM (F_1) over 0 level of FYM. An application of FYM @ 20 t ha^{-1} recorded significantly the highest value for OC, available N, P_2O_5, K_2O, Zn, Fe, Mn and Cu content in soil, except Cd. Addition of FYM decreased pH due to released organic acids upon decomposition of FYM and increased EC might be due to accumulation of cation in the soil solution. Application of FYM @20 t ha^{-1} improve the physico-chemical and biological properties of soil and adding organic matter in the soil. These results are supported by (Mehta *et al.* 2004) [17], (Totawat *et al.* 2001) [18], (Ganai and Singh, 1988) [19], (Reddy and Reddy, 1998) [20], (Sharma *et al.* 2000) [21], (Parmar *et al.* 2012) and (Patiram and Mali, 2004) [23].

4.3 Effect of Cd

The highest Cd availability (19.46 ppm) was noticed under Cd_{80} level, which was more than maximum (2.30 ppm) concentration in soil is permitted under European Community Regulation (Wild, A. 1993) [24]. The level of available Cd may be reach to hazardous level in the soil if it will be incorporated in the soil through any means. Availability of all nutrients (N, P, K, Fe, Cu, Mn and Zn) was significantly reduced under 80.00 ppm of applied Cd. And similar trend was observed by (Jha *et al.* 2001 and Ghani, 2010) [25, 15].

Table 2: Effect of FYM and cadmium on available nutrient status (mg kg^{-1}) in soil after harvest and Cd at 30 DAS

Treatments	$EC_{2.5}$	$pH_{2.5}$	OC	N	P_2O_5	K_2O	CD-30 DAS	Zn	Fe	Mn	Cu	Cd
Type of soils												
C_1: Maize	0.259	7.44	0.38	229.77	31.78	282.35	9.43	4.36	8.73	12.20	1.98	8.12
C_2: Sorghum	0.257	7.50	0.39	224.40	30.56	276.98	8.94	4.04	8.47	11.86	1.84	7.53
S. Em. ±	0.00073	0.019	0.0020	1.35	0.27	1.83	0.08	0.04	0.11	0.12	0.03	0.08
C.D. at 5%	0.0021	0.055	0.0059	3.85	0.77	5.23	0.24	0.10	0.31	0.34	0.07	0.24
Levels of FYM												
F_0: 0 t ha^{-1}	0.252	7.55	0.37	221.43	30.53	273.24	10.10	3.53	8.18	11.50	1.75	8.56
F_1: 20 t ha^{-1}	0.263	7.39	0.40	232.73	31.81	286.08	8.27	4.87	9.02	12.57	2.08	7.10
S. Em. ±	0.00073	0.019	0.0020	1.35	0.27	1.83	0.08	0.04	0.11	0.12	0.03	0.08
C.D. at 5%	0.0021	0.055	0.0059	3.85	0.77	5.23	0.24	0.10	0.31	0.34	0.07	0.24
Levels of Cd												
Cd_0: 0 ppm	0.252	7.83	0.34	234.25	35.88	293.52	0.08	5.68	11.71	14.18	2.46	0.06
Cd_{10}: 10 ppm	0.253	7.65	0.36	231.58	33.91	285.75	3.25	5.05	9.88	13.11	2.18	2.51
Cd_{20}: 20 ppm	0.257	7.43	0.38	229.25	30.74	278.47	6.79	4.26	8.76	12.24	1.92	5.36
Cd_{40}: 40 ppm	0.260	7.32	0.40	222.08	28.52	274.75	13.62	3.18	7.19	11.13	1.64	11.75
Cd_{80}: 80 ppm	0.268	7.14	0.44	218.25	26.80	265.84	22.18	2.83	5.47	9.49	1.36	19.46
S.Em. ±	0.0011	0.030	0.0032	2.13	0.43	2.90	0.13	0.06	0.17	0.19	0.04	0.13
C.D. at 5%	0.0033	0.08	0.009	6.08	1.22	8.28	0.38	0.16	0.50	0.54	0.12	0.37
CV %	1.56	1.43	2.91	3.25	4.76	3.59	5.06	4.69	7.01	5.41	7.31	5.75
Significant interactions	NS	NS	NS	NS	NS	NS	F × Cd C × Cd	F × Cd	F × Cd	NS	NS	F × Cd C × Cd
Initial status												
Initial	0.22	7.9	0.33	220.37	34.8	292.57	0.05	1.36	7.66	12.86	0.78	0.05

4.4 Interaction effect

C × Cd interaction was found to be significant in terms of DTPA-Cd at 30 DAS and 60 DAS and F × Cd interaction was found to be significant in terms of DTPA-Cd at 30 DAS and 60 DAS status of the soil after harvest of maize and sorghum crop.

4.4.1 Effect of C × Cd

The C × Cd interaction significantly increased the Cd availability at 30 DAS and after harvest of maize and sorghum (table 2a). In each crop, Cd availability was increased significantly under each Cd level. It might be due to genetic variability between the crops. These results were similar to findings of Jha (2001) [25] after harvest of chickpea and wheat crops at Anand.

Table 2a: Interaction effect of crop and cadmium (C × Cd) on available Cd status (mg kg^{-1}) in soil at 30 and 60 DAS

Cd levels Type of Crops	Cd_0	Cd_{10}	Cd_{20}	Cd_{40}	Cd_{80}
DTPA-Cd 30 DAS					
C_1	0.10	3.19	7.09	14.18	22.57
C_2	0.07	3.31	6.49	13.05	21.79
C × Cd	S. Em. ± 0.19			C.D. at 5% 0.54	
DTPA-Cd 60 DAS					
C_1	0.07	2.64	5.82	12.30	19.78
C_2	0.05	2.38	4.90	11.20	19.14
C × Cd	S. Em. ± 0.28			C.D. at 5% 0.63	

4.4.2 Effect of F × Cd interaction

Data on interaction effect of FYM and Cd application with respect to Cd status in soil was found significant (Table 2b). Application of FYM @ 20 t ha^{-1} reduced the availability of Cd in soil at 30 DAS and at harvest. This might be due to presence of carboxyl, hydroxyl and phenoxy group in FYM chelate the applied Cd in soil which ultimately decreased its availability.

Table 2b: Interaction effect of FYM and cadmium on available Cd status (mg kg^{-1}) in soil after harvest

Cd levels Levels of FYM	Cd_0	Cd_{10}	Cd_{20}	Cd_{40}	Cd_{80}
DTPA- Cd 30 DAS					
F_0	0.10	3.92	7.66	15.23	23.62
F_1	0.07	2.59	5.92	12.00	20.75
F × Cd	S. Em. ± 0.22			C.D. at 5% 0.58	
Available Cd 60 DAS					
F_0	0.07	2.90	6.11	13.04	20.67
F_1	0.05	2.12	4.61	10.47	18.26
F × Cd	S. Em. ± 0.18			C.D. at 5% 0.53	
Available Fe					
F_0	11.36	9.51	8.16	6.81	5.07
F_1	12.07	10.26	9.36	7.56	5.87
F × Cd	S. Em. ± 0.25			C.D.at 5% 0.70	
Available Zn					
F_0	5.05	4.34	3.59	2.37	2.30
F_1	6.31	5.76	4.93	3.99	3.35
F × Cd	S. Em. ± 0.08			C.D. at 5% 0.23	

5. Conclusion

Based on the results of the experiment, it could be concluded that Application of FYM @ 20 t ha^{-1} significantly reduced Cd content in soil over no FYM application. Significant rise in cadmium content in soil at 30 DAS were noticed with each increasing level of applied cadmium.

6. References

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