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

Dr. GJ Mistry
Assistant Research Scienstist Micronutrient Research Project (ICAR), Anand Agricultural University, Gujarat, India

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

Dr. VP Ramani
Associate Research Scientist Micronutrient Research Project (ICAR) Anand Agricultural University, Gujarat, India

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

Effect of Cd and FYM on growth and yield of forage sorghum and forage maize

Patel Vimal N, Dr. GJ Mistry, Patel Dipak H and Dr. VP Ramani

Abstract
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 repetation. 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. Maize (C_1) had taller plant height, more number of leaves, shoot weight, root weight and total dry matter yield as compared to sorghum (C_2) is mainly due to genetic makeup of crops. In maize and sorghum crops Cd_0F_1 treatment recorded significantly the highest yield. Under $Cd_{80}F_0$ treatment the minimum yield in both the crops were recorded.

Keywords: Cadmium, FYM, Maize, Sorghum, Yield

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.

FYM is the source of primary, secondary and micronutrient to the plant growth. It is a constant source of energy for hetrotropic 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) [3] as well as improves soil physical properties (Chen *et al*., 1996) [2] and can be used to reduce heavy metal hazards in plants (Yassen *et al.,* 2007) [20]. 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 [11]; Mahmood, 2010) [14]. With these background, a pot trial was undertaken in order to generate location specific information. The study was conducted during *summer*, 2014 at pot house, modern laboratory, Micronutrient Research Project (I.C.A.R), Anand Agricultural University, Anand.

Material and Methods
The present investigation, a pot experiment was conducted during *summer* season of 2014 in the pot house, modern laboratory, Micronutrient Research Project (I.C.A.R), Anand Agricultural University, Anand, Gujarat. The soil is representative of the region and is locally known as *"Goradu"* soil. The texture of the soil is loamy sand. The treatment consisted5 levels of cadmium (Cd_0: 0 ppm, Cd_{10}: 10 ppm, Cd_{20}: 20 ppm, Cd_{40}:40 ppm and Cd_{80}: 80 ppm), 2 levels of FYM (F_0: 0 tha^{-1} and F_1: 20 tha^{-1}) and 2 crops [C_1: Maize (*Zea mays* L.) and C_2: Sorghum (*Sorghum bicolor* L.)] in factorial completely randomized design with 3 replication. Fifteen kilograms of 2mm sieved soil has been taken in each polythene lined earthen pot and calculated quantities of graded levels of Cd (Cd_0,Cd_{10},Cd_{20},Cd_{40} and Cd_{80}) in the form of $CdCl_2.H_2O$ was added as per technical programme, FYM was mixed properly as per treatments and kept it for stabilization for one month period. Pots were regularly watered and weed free condition were maintained till 60 DAS required for vegetative growth. The ancillary observations like plant height, leaf number at 30 DAS and at the time of harvesting were taken

according with the growth of the crops. Top dressing of nitrogen with Urea was done at 30 DAS after sowing. The major and secondary nutrients were expressed in percent while, micronutrients contents were expressed in ppm on oven dry basis. Micronutrient content in soil and plant and dry matter yield calculated by following formulas.

$$\text{Micronutrient content in soil (mg kg1)} = \text{(S-B)} \times \frac{\text{Volume of DTPA extractant}}{\text{Wt. of soil sample}}$$

$$\text{Micronutrient content in plant (mg kg1)} = \text{(S-B)} \times \frac{\text{Final volume made}}{\text{Wt. of plant sample taken}}$$

S = Sample reading in AAS instrument
B = Blank reading

$$\text{Dry matter content (\%)} = \frac{\text{Oven dry fodder weight (g)}}{\text{Fresh green fodder weight (g)}} \times 100$$

$$\text{Dry matter yield (g pot-1)} = \frac{\text{Green forage yield (g pot-1)} \times \text{Dry matter content (\%)}}{100}$$

Results and Discussion

Table 4.1: Effect of different treatments on germination days of maize and sorghum

Treatments	Germination Days
Type of crops (C)	
C1: Maize	3.57
C2: Sorghum	6.22
S.Em.±	0.10
C.D. at 5%	0.21
Levels of FYM (F)	
F_0: 0 t ha^{-1}	4.68
F_1: 20 t ha^{-1}	5.10
S.Em.±	0.10
C.D. at 5%	0.21
Levels of Cd (Cd)	
Cd_0: 0 ppm	4.59
Cd_{10}:10 ppm	4.67
Cd_{20}:20 ppm	4.94
Cd_{40}:40 ppm	4.98
Cd_{80}:80 ppm	5.29
S.Em.±	0.12
C.D. at 5%	0.34
Interactions C× Cd	Sig.
C.V. %	8.49

Table 4.1a Interaction effect of crops and cadmium (C × Cd) on germination days of maize and sorghum

Cd levels / Type of crops	Cd_0	Cd_{10}	Cd_{20}	Cd_{40}	Cd_{80}
C_1	3.26	3.28	3.17	3.43	4.13
C_2	5.91	5.93	6.21	6.45	6.60
C × Cd	S.Em.±C.D. at 5%0.16 0.48				

Growth: The data on germination days of maize (C_1) and Sorghum (C_2) as affected by FYM and Cd levels are presented in Table 4.1.Germination days (3.57 days) of maize were significantly lower than sorghum (6.22 days). The differences in plant is mainly due to genetic makeup of crops, as initial growth of maize is faster than sorghum (Liu *et al.*, 2011) [12].Application of FYM @ 20 t ha^{-1} (F_1) gave significantly less germination days (4.68 days) as compared to no FYM (F_0) application (5.10 days). The decrease in germination days under F_1 could be mainly due to improvement in physic-chemical and biological properties of soil due to increase in organic carbon status of soil and supplying secondary and micronutrients. And the mitigating effect of FYM on Cd toxicity on plant growth and less availability of Cd due to binding and chelating capacity of FYM (Haghiri *et al.*, 1974) [7] found the similar results. Application of Cd significantly reduced the germination days of maize and sorghum plant. The germination days were decreased by 13.23 per cent when 80 ppm Cd (Cd_{80}) was added to the soils over control (Cd_0). Except Cd_0 at par with Cd_{10} and Cd_{40} at par with Cd_{80} treatments. The decrease in seed germination can be attributed to the accelerated breakdown of stored food materials in seed by the application of cadmium. Reduction in seed germination can also be attributed to alterations of selection permeability properties of cell membrane. (Muhammad *et al.,* 2008) [14]. The interaction effects of C × Cd was found to be significant in respect of germination days and the data pertaining to these interactions are presented in Tables 4.1a.

The data presented in Table 4.1a indicated that the germination days was significantly the lowest under treatment combination C1Cd0 (3.26 day). The significant increase in germination days was noted under treatment combination C2Cd80 (6.60 day) over rest of the combinations. The data on plant height of maize (C_1) and Sorghum (C_2) as affected by FYM and Cd levels are presented in Table 4.2.Plant height (45.69 cm and 67.93 cm) of maize was significantly higher than sorghum (36.93 and 56.30 cm) at 30 and 60 DAS. The differences in plant is mainly due to genetic makeup of crops, as initial growth of maize is faster than sorghum (Liu *et al.,*2011) [12].Application of FYM @ 20 t ha^{-1} (F_1) recorded significantly higher plant height (51.34 cm and 72.65 cm) as compared to no FYM (F_0) application (31.18 and 51.58 cm) at both 30 and 60 DAS. The increase in plant height under F_1 could be mainly due to improvement in physico-chemical and biological properties of soil due to increase in organic carbon status of soil and supplying secondary and micronutrients. The mitigating effect of FYM on Cd toxicity on plant growth and less availability of Cd due to binding and chelating capacity of FYM (Haghiri *et al.*, 1974) [7], (Yaseen *et al.*, 2007) [20], (Sushila and Giri, 2008) [19], (Gangwar and Niranjan, 1991) [4] and (Singh *et al.*, 1999) [9, 18] found the similar results. Application of Cd significantly reduced the plant height (at 30 DAS and 60 DAS) of maize and sorghum plants (Table 4.2). At 30 DAS the plant height was decreased by 51.51 per cent and at 60 DAS it was decreased to 54.44 per cent when 80 ppm Cd (Cd_{80}) was added to the soils over control (Cd_0). At each increasing levels of applied Cd from Cd_{10}, there was significant reduction in plant height at both the intervals except at 60 DAS in case of Cd_{40} and Cd_{80} levels, which were at par.

The reduction in plant height due to increasing Cd application rates was reported by several workers (Gupta and Dixit, 1992 [5] for sorghum, pearl millet, maize, green gram, cluster bean, cowpea crops; Sarkunan *et al*., 1995 [17] and Gupta *et al*., 1997 [6] for rice; Liu *et al.,* 2011 [12] for sorghum). This reduction in plant height was due to increased level of Cd content in shoot and other plant parts, which interfered with translocation of various metabolites and nutrients (Mahler *et al*., 1978) [13]. (Huang *et al*., 1974) [8] reported that the plant height reduction was also correlated with photosynthetic processes. The net photosynthesis and chlorophyll content in plant generally decreased with Cd concentration. This inhibition may primary be attributed to the closure of stomata. The interaction effects of C × F, C × Cd, F × Cd and C × Cd × F were found to be significant in respect of plant height at 30 DAS and 60 DAS. The data pertaining to these interactions are presented in Tables 4.2a, 4.2b, 4.2c and 4.2d.The data presented in Table 4.2a on the interaction effect between Crops and FYM levels on plant height of shoot at 30 DAS revealed that the treatment combination C_1F_1 recorded significantly the highest plant height at 3O DAS (50.01 cm) and (72.39 cm) at 60 DAS, while significantly the lowest plant height were noted under C_2F_0 combination at 30 DAS (29.19 cm) and 60 DAS (47.18 cm).The data presented in Table 4.2b indicated that the plant height (at 30 and 60 DAS) was significantly the highest under treatment combination C_1Cd_0. The significant decrease in plant height was noted under treatment combination C_2Cd_{80} over rest of the combinations bearing treatment combination C_2Cd_{40}. These results indicate that the effect of higher levels of cadmium was more pronounced in sorghum as compared to maize. The data presented in Table 4.2b indicated that the plant height (at 30 and 60 DAS) was significantly the highest under treatment combination C_1Cd_0. The significant decrease in plant height was noted under treatment combination C_2Cd_{80} over rest of the combinations bearing treatment combination C_2Cd_{40}. These results indicate that the effect of higher levels of cadmium was more pronounced in sorghum as compared to maize. The plant height (Table 4.1c) was significantly higher in FYM treated soil (F_1) as compared to no FYM treated (F_0) soil at 30 and 60 DAS in both the crops. There was gradual decrease in plant height with the increase in Cd levels at 30 and 60 DAS. However application of FYM reduced the toxicity of Cd through phytostabilization of Cd in soil and thus increased plant height. When Cd_{40} and Cd_{80} levels are compared the addition of FYM significantly improved plant height at 30 and 60 DAS, the decrease in toxicity was 1.5 to 2 folds. The interaction effect of C × Cd × F showed that the significantly the highest plant height was noted under $C_1Cd_0F_1$ at 30 DAS (67.89 cm) and at 60 DAS (104.20 cm), while significantly the lowest plant height was registered under $C_2Cd_{80}F_0$ at 30 DAS (12.15 cm) and at 60 DAS (24.18 cm), which differed significantly from rest of the treatment combination except $C_2Cd_{10}F_1$and $C_2Cd_{40}F_0$ combination. Similar trend was also found in case of FYM application, where in $C_2Cd_{80}F_0$ recorded significantly lower plant height then the rest of the combinations of Cd levels and FYM under sorghum crop at 30 and 60 DAS.

Table 4.2a: Interaction effect of crops and FYM (C × F) on Plant height (cm) of maize and sorghum

Type of Crops \ FYM levels	F_0	F_1
30 DAS		
C_1	41.18	50.01
C_2	29.19	44.66
C × F	S.Em.±C.D. at 5% 0.832.39	
60 DAS		
C_1	63.47	72.39
C_2	47.18	65.42
C × F	S.Em.±C.D. at 5% 1.183.38	

Table 4.2b: Interaction effect of crops and cadmium (C × Cd) on Plant height (cm) of maize and sorghum

Type of crops \ Cd levels	Cd_0	Cd_{10}	Cd_{20}	Cd_{40}	Cd_{80}
At 30 DAS					
C_1	60.75	49.58	47.71	36.81	32.95
C_2	52.61	46.38	40.01	23.78	21.25
C × Cd	S.Em.± C.D. at 5%1.32 3.78				
At 60 DAS					
C_1	98.04	75.16	69.10	51.02	45.42
C_2	81.53	69.14	59.53	35.81	30.38
C × Cd	S.Em.±C.D. at 5%1.87 5.34				

Table 4.2c: Interaction effect of FYM and cadmium (F × Cd) on Plant height (cm) of maize and sorghum

FYM levels \ Cd levels	Cd_0	Cd_{10}	Cd_{20}	Cd_{40}	Cd_{80}
At 30 DAS					
F_0	48.27	34.99	30.25	22.61	19.50
F_1	65.09	61.97	57.48	38.81	33.35
F × Cd	S.Em.± C.D. at 5%1.323.78				
At 60 DAS					
F_0	81.95	58.62	47.88	35.15	30.28
F_1	97.62	85.68	72.75	51.68	47.52
F × Cd	S.Em.± C.D. at 5%1.90 5.44				

Table 4.2d: Interaction effect of crop, cadmium and FYM (C × Cd × F) on Plant height (cm) of maize and sorghum

Type of Crops	Cd levels	FYM levels	
		F_0	F_1
30 DAS			
C_1	Cd_0	53.61	67.89
	Cd_{10}	42.25	59.91
	Cd_{20}	36.69	58.74
	Cd_{40}	28.08	46.03
	Cd_{80}	27.60	38.15
C_2	Cd_0	42.92	62.30
	Cd_{10}	34.74	57.03
	Cd_{20}	23.81	51.22
	Cd_{40}	18.96	32.60
	Cd_{80}	12.15	26.54
C × Cd × F		S.Em±C.D. at 5%1.87 5.34	
60 DAS			
C_1	Cd_0	91.87	104.20
	Cd_{10}	75.93	84.40
	Cd_{20}	58.00	75.20
	Cd_{40}	45.69	60.36
	Cd_{80}	38.69	51.25
C_2	Cd_0	72.03	91.03
	Cd_{10}	61.30	86.97
	Cd_{20}	40.76	77.30
	Cd_{40}	29.61	44.78
	Cd_{80}	24.18	39.01
C × Cd × F		S.Em.± C.D. at 5%2.647.55	

Table 4.2: Effect of different treatments on Plant height (cm) of maize and sorghum at 30 and 60 DAS

Treatments	30 DAS	60 DAS
Type of crops (C)		
C_1: Maize	45.59	67.93
C_2: Sorghum	36.93	56.30
S.Em.±	0.59	0.84
C.D. at 5%	1.69	2.39
Levels of FYM (F)		
F_0: 0 t ha^{-1}	31.18	51.58
F_1: 20 t ha^{-1}	51.34	72.65
S.Em.±	0.59	0.85
C.D. at 5%	1.69	2.43
Levels of Cd (Cd)		
Cd_0:0 ppm	56.68	89.78
Cd_{10}:10 ppm	47.98	72.15
Cd_{20}:20 ppm	43.86	64.32
Cd_{40}:40 ppm	30.30	43.42
Cd_{80}:80 ppm	27.48	40.90
S.Em.±	0.94	1.34
C.D. at 5%	2.67	3.84
Interactions C ×F C× Cd F × Cd C × CD × F	Sig.	Sig.
C.V. %	7.84	7.37

Yield

The results revealed that the total green forage yield was significantly influenced due to crops. Among the crops significantly higher yield of (50.22 g pot^{-1}) was reported in maize than sorghum (45.29 g pot^{-1}). The total green forage yield was 9.81 percent higher in maize than sorghum crop (Table 4.4). The findings are in close accordance with that reported by (Dahiya *et al.,* 1987) [3] for maize, (Petrsoudek *et al*., 2012) [16] for sorghum crop, (Kibria *et al.,* 2006) [10] and (Sarkunan *et al.,* 1995) [17] for rice crop. The green forage yields (Table 4.5) were significantly influenced due to FYM application @ 20 t ha^{-1}. The green forage yield of maize plant increased to 52.09 per cent over control (F_0). The higher green forage yield with FYM application might be due to the beneficial effect of FYM to its contribution in supplying additional plant nutrients, improvement of soil physical conditions and biological process of soil (Dahiya *et al.,* 1987) [3] and similar results were found by (Sushila and Giri, 2008) [19], (Gangwar and Niranjan, 1991) [4]. The results furnished in Table 4.5 revealed that the application of Cd significantly reduced the green forage yield of maize and sorghum with increasing Cd levels. The green forage yield of both plant decreased to 81.97 per cent, respectively when 80 ppm Cd (Cd_{80}) was added to the soils as compared to control (Cd_0). The decrease in green forage yield due to increased Cd level could partly be owing to its toxic effect and partly due to its ionic imbalance (Dahiya *et al.,* 1987) [3]. The interaction effects of C × F, C × Cd, F × Cd and C × Cd × F were found to be significant in respect of green forage yield and the data pertaining to these interactions are presented in Tables 4.5a, 4.5b, 4.5c and 4.5d.The data presented in Table 4.5a on the interaction effect between Crops and FYM levels on green forage yield revealed that the treatment combinationC_1F_1 recorded significantly the highest green forage yield (68.96 g pot^{-1}), while significantly lowest green forage yield were noted under C_2F_0 combination at (30.39 g pot^{-1}). In the green forage yield per cent increasing was 54.35 in maize and 49.50 in sorghum. The data presented in Table 4.5b indicated that the green forage yield was significantly the highest under treatment combination C_1Cd_0 (70.31 g pot^{-1}). The significant decrease in green forage yield was noted under treatment combination C_2Cd_{80} (9.03 g pot^{-1}) over rest of the combinations. These result indicate that the effect of higher levels of cadmium was more pronounced in sorghum as compared to maize. The green forage yield (Table 4.5c) was significantly higher in FYM treated soil (F_1) as compared to no FYM treated (F_0) soil. There was gradual decrease in leaf number, plant height as well as green forage yield with the increase in Cd levels. However, application of FYM reduced the toxicity of Cd through phytostabilization of Cd in soil and thus increased green forage yield. Whereas, the significant reduction in green forage yield was recorded with graded levels of Cd. Application of FYM may reduce the toxicity of Cd through phytostabilization of Cd in soil and thus increased green forage yield. It is graphically illustrated in fig. 9.The interaction effect of C × Cd × F showed that the significantly the highest green forage yield was noted under $C_1Cd_0F_1$ (83.64 g pot^{-1}), while significantly the lowest green forage yield was registered under $C_2Cd_{80}F_0$ (5.66 g pot^{-1}), which differed significantly from rest of the treatment combination. Similar trend was also found in case of FYM application, where in $C_2Cd_{80}F_0$ recorded significantly lower green forage yield then the rest of the combinations of Cd levels and FYM under sorghum crop.

Table 4.5: Effect of different treatments on green forage yield (g pot^{-1}) of maize and sorghum at harvest

Treatments	At harvest
Type of crops (C)	
C1: Maize	50.22
C2: Sorghum	45.29
S.Em.±	0.52
C.D. at 5%	1.49
Levels of FYM (F)	
F_0: 0 t ha^{-1}	30.94
F_1: 20 t ha^{-1}	64.58
S.Em. ±	0.52
C.D. at 5%	1.49
Levels of Cd (Cd)	
Cd_0: 0 ppm	75.56
Cd_{10}:10 ppm	57.72
Cd_{20}:20 ppm	50.39
Cd_{40}:40 ppm	41.50
Cd_{80}:80 ppm	13.62
S.Em. ±	0.82
C.D. at 5%	2.36
Interactions C ×F C× Cd Cd × F C × Cd × F	Sig.
C.V. %	5.98

Table 4.5a: Interaction effect of crops and FYM (C × F) on green forage yield (g pot^{-1}) of maize and sorghum

FYM levels / Type of Crops	F_0	F_1
At hatvest		
C_1	31.48	68.96
C_2	30.39	60.19
C × F	S.Em.± C.D. at 5%0.74 2.11	

Table 4.5b: Interaction effect of crops and cadmium (C × Cd)on green forage yield (g pot^{-1}) of maize and sorghum

Cd levels / Type of crops	Cd_0	Cd_{10}	Cd_{20}	Cd_{40}	Cd_{80}
At Haarvest					
C_1	79.31	60.64	55.14	45.31	18.22
C_2	71.81	54.81	45.63	37.69	9.03
C × Cd	S.Em. ±C.D. at 5%1.173.33				

Table 4.5c: Interaction effect of FYM and cadmium (F × Cd) on green forage yield (g pot^{-1}) of maize and sorghum

Cd levels / FYM levels	Cd_0	Cd_{10}	Cd_{20}	Cd_{40}	Cd_{80}
At Harvest					
F_0	65.14	31.47	27.52	22.80	7.76
F_1	85.97	81.32	77.97	55.47	19.49
F × Cd	S.Em.±C.D. at 5% 0.173.33				

Table 4.5d: Interaction effect of crop, cadmium and FYM (C × Cd × F) on green forage yield of maize and sorghum

Type of Crops (C)	Cd levels (Cd)	FYM levels (F)	
		F_0	F_1
At harvest			
C_1	Cd_0	59.97	83.64
	Cd_{10}	32.64	90.97
	Cd_{20}	30.31	77.64
	Cd_{40}	24.64	65.97
	Cd_{80}	9.86	26.57
C_2	Cd_0	70.31	88.31
	Cd_{10}	32.64	76.97
	Cd_{20}	30.41	71.31
	Cd_{40}	12.96	44.97
	Cd_{80}	5.66	12.41
C × Cd × F		S.Em.± C.D. at 5%1.654.71	

Conclusion

The experimental results revealed that application of Cd @ 80 mg kg^{-1} in soil significantly reduced plant height and leaf number at 30 and 60 DAS, in both the forage crops over other levels of cadmium. The effect was mitigated by FYM application @ 20 t ha^{-1}.In absence of cadmium (Cd_0) both the crops recorded maximum of plant height and leaf number at both the stages (30 and 60 DAS) of their measurement.

The dry matter yield of shoot, root and total dry matter yield also followed the same trend in both the crops. If we look through the data even application of Cd @ 10 ppm had significant depressing effect on all the parameters measured. However, in case of sorghum (C_2) plant height was at par under Cd_0F_1 and $Cd_{10}F_1$ treatments. Between two crops, maize (C_1) had taller plant height, more number of leaves, shoot weight, root weight and total dry matter yield as compared to sorghum (C_2), probably due to variation in the species of cereals.

The effect of cadmium application on green forage yield was significant for both the crops. In case of maize (C_1) Cd_0F_1 treatment recorded significantly the highest yield, while in case of sorghum (C_2) Cd_0F_1 gave significantly the highest yield. The minimum yield in both the crops was noted under $Cd_{80}F_0$ treatment.

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