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Effect of farm yard manure on chemical fractionation of cadmium and its bio-availability to maize crop grown on sewage irrigated coarse textured soil

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Abstract

Cadmium is a potentially toxic heavy metal that enters food chain from the soil through various anthropogenic sources. Availability of metal ions in contaminated soils can be reduced by the addition of organic amendments. In this study, effect of organic matter –farm yard manure (FYM) amendment on fractionation and availability of Cd to maize was evaluated.A green house experiment was conducted to determine the toxicity and uptake of Cd by maize in sandy loam soil with and without organic matter. Four levels of Cd(0, 10, 20 and 40 mg kg^{-1}soil) and two levels of FYM (0 and 20 tonnes ha^{-1}) with three replication in a completely randomized factorial design. Concentration of Cd in maize increased with increasing rate of Cd application. Application of organic matter increased the dry matter yield of maize while reduced the uptake of metal. All the fractions exhibited increase with Cd rates. The addition of organic amendment declined significantly the concentration of water soluble and exchangeable Cd, but increased the amounts of these metals into less mobile fractions (Fe/Mn oxide, organic matter and residual). Dominance of insoluble forms of Cd after the application of organic amendments may be ascribed to the increases of soil OM, pH, EC and available P contents which caused transformation or redistribution of the sorbed phases. This resulted in increasing Cd retention in the more persistent fractions with application of FYM at the expense of reductions in the loosely bound fractions. Thus FYM appears to be agronomically feasible way to off set the adverse effect of Cd toxicity.

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Introduction

Public concern over the harmful effects of environmental pollution during recent decade as a result of enhanced understanding of the risk to human health are genuine and legitimate. Agricultural lands show elevated levels of pollutant elements due to various anthropogenic activities such as continuous use of sewage water largely contaminated with mixed industrial effluents, sewage sludge and fertilizers (Indra and Sivaji, 2006; Aulakh, *et al.*, 2009). Among heavy metals, cadmium is the only metal which has been identified as most potentially hazardous element to micro organism, plants, animals and human beings. Cadmium, because it is readily absorbed by plants is a major concern for food poisoning also. The recent interest in Cd content in plants arises from the investigations revealing the harmful health effect of dietary intake of Cd. It is released into the environment by industries engaged in electroplating, pigments, plastics, stabilizers and nickel cadmium batteries (Bernard, 2008). It is considered as a cumulative poison and is highly toxic to humans, with a biological half-life of 17-30 years.

Among remediation options, physical methods such as vitrification and evacuation of polluted soils and its disposal to land fill sites are quite expensive. The major problem associated with phyto-remediation is low metal removing rates (McGrath *et al.,* 2002). Hence, there has been an increasing interest in the immobilization of metals using range of inorganic and organic material like lime, phosphate, organic manures and zeolites (Datta *et al*., 2007; Dheri *et al*., 2007). However, using farm yard manure is a cost-effective option as it acts as pollutant ameliorant and thus expected to mitigate the toxic effect of cadmium.

Further speciation into various geochemical forms of heavy metals including Cd in contaminated soils affecting their solubility is gaining importance to fully understand the behavior of cadmium in soil which directly influence their availability to plants (Ma and Rao, 1999; Ghafoor *et al.,* 2008). Although the total metal concentration in many contaminated soils may be high, the phyto-available fraction is usually very low due to the strong association of metal with organic matter, Fe–Mn oxides, and clays, and precipitation as carbonates, hydroxides, and phosphates (McBride, 1995). The magnitude of these forms besides physico-chemical characteristics of the soils also depend on the rates of metal loading from inorganic or organic sources. A change in chemical form may influence the uptake by plants and help to reduce/enhance the toxicity.

In Punjab (India), maize, as a fodder, is grown along with vegetables on soils receiving sewage irrigation largely contaminated with industrial effluents. These soils have been reported to contain high amount of heavy metals compared to normal soils (Khurana *et al*., 2003). Although various amendments has been tried for different crops but the work on efficient and cost efficient ameliorative measure affecting the availability of cadmium to this crop is still not elucidated. Therefore, it was felt to examine FYM on the fractionation of cadmium in soils and consequently affecting its bioavailability to maize crop.

Materials and Methods

A pot culture experiment was conducted in a green house on sewage irrigated soil which has been receiving sewage irrigation for the last twenty years. The physico-chemical properties of the experimental soil and FYM are given in Tables 1 and 2. The pots were filled with 5 kg thoroughly mixed air dried soil and lined inside with polythene.

Treatment of Cd consisted (0,10,20 and 40 mg kg^{-1}) and two levels of FYM (0 and 20 tonnes ha^{-1}) with three replications in a completely randomized design. The soils moisture was maintained to field capacity and kept in the green house for 30 days to attain equilibrium. Basal dose of nitrogen, phosphorus (P_2O_5) and potassium (K_2O) were applied at rate of 100,60 and 60 mg kg^{-1} soil respectively through their analytical grade chemicals i.e. urea, dihydrogen potassium phosphate and potassium chloride respectively at the time of sowing. Twelve seeds of maize were sown in each pot under optimum moisture condition. After germination thinning was done to maintain six plants per pot. The soils in the pots were irrigated regularly with de-ionized water. Thereafter, representative soil sample from each pot was taken with the help of stainless steel tube auger. The samples were dried, ground, sieved and stored in polythene bags for chemical analysis.

Organic carbon, pH, electrical conductivity, calcium carbonate, available N, P, K and total contents of Cd were determined by standard methods (Page, 1982). DTPA extractable micronutrients were determined by employing the method of Lindsay and Norvell (1978).The crop was harvested 45 days after sowing. After harvest shoot samples were taken from each pot and washed with tap water, dipped in 0.01 N HCl taken in a plastic tub for few seconds, distilled and deionised water, respectively. Samples were dried in air and then at a temperature of 60°C in hot air oven. The dried samples were weighed and ground in willey mill and were digested in a di-acid mixture of HNO_3 and $HClO_4$ in a ratio of 4:1 and the digests were analyzed for total Cd using an atomic absorption spectrophotometer.

A seven step sequential extraction procedure was followed to evaluate the different chemical forms of fraction of Cd such as exchangeable + water soluble, carbonates, organic mater complexed, Mn-oxide bound, occluded in amorphous and crystalline Fe oxide and residual mineral fraction. Here sequential extraction procedure adopted by Singh *et al.* (1988) was used as described in table 3. Reagents used in fractionation scheme were selected from those cited in the literature as being selective for specific chemical from in soil. It is pertinent to mention here that essential conditions like boiling, evaporating, digestion and shaking were fulfilled during sequential procedure.

Results and Discussion

Mean dry matter yield of maize decreased significantly with increasing rates of Cd in soil both with and without addition of

Table 1 : Physico-chemical properties of the experimental soil

Properties	Value ±SE	
pH*	7.98± 0.075	
EC(dS m^{-1})*	0.71±0.029	
Organic carbon (%)	0.52± 0.025	
$CaCO_3$ (%)	0.75±0.028	
CEC(C mol (P^{+}) kg^{-1}	6.12±0.072	
Sand (%)	80.40±1.36	
Silt (%)	11.80±0.31	
Clay (%)	7.80±0.27	
Texture	Loamy sand	
Available N (kg ha^{-1})	325±7.76	
Available P (kg ha^{-1})	15.2±0.51	
Available K (kg ha^{-1})	210±4.04	
	DTPA	**Total**
Zinc (mg kg^{-1} soil)	0.98± 0.06	32.92 ± 1.35
Iron (mg kg^{-1} soil)	10.20± 0.64	15140±282.1
Manganese (mg kg^{-1} soil)	5.80± 0.31	310±9.45
Copper (mg kg^{-1} soil)	0.67±0.045	12.3±0.91
Cadmium (mg kg^{-1} soil)	0.21± 0.015	1.74±0.14

*1 :2 Soil water suspension

Table 2 : Chemical composition of farm yard manure

Characteristics	Content ± SE
Organic carbon (%)	16.78 ±0.38
pH*	8.18 ±0.23
EC (dS m^{-1})*	3.70±0.26
Total nitrogen (%)	0.64±0.030
Total phosphorus (%)	0.29±0.028
Total Potassium (%)	0.72±0.32
Iron (mg kg^{-1})	1980±9.16
Manganese (mg kg^{-1})	182±3.05
Copper (mg kg^{-1})	12.7±0.58
Zinc (mg kg^{-1})	55.4±0.98
Cadmium (mg kg^{-1})	0.34±0.031

*1:4 farm yard manure: water suspension

FYM**.** The effect of the added Cd was more pronounced at highest rate of its application. Mean dry matter yield of maize at 45 days of growth, significantly decreased from 14.3 g pot $^{-1}$ to 11.2, 9.2 and 6.8 g pot $^{-1}$ when the rate of cadmium was increased from 0 to 40 mg kg^{-1}soil irrespective of FYM levels (Table 4). The depressive effect of Cd on yield was consistent with the results of Khurana *et al.* (2006) and Sidhu and Khurana (2010) in maize, raya and spinach. Decline in yield in various crops is attributed to phyto-toxicity of Cd on the metabolism of crops such as inhibition of various enzymes activities and induction of oxidative stress (Sandalio *et al*., 2001) including alterations in enzymes of antioxidant defense system (Romero –Puertess *et al*., 2002).

Different mathematical and regression models such as linear, quadratic, power, log and exponential functions were tested to find out the best fit for the dry matter yield when its value was regressed with levels of cadmium. It was found that response curve was well described by exponential (R^2=0.91) and quadratic (R^2=0.94) functions. Oliver *et al.* (1994) also obtained best fit with exponential model corresponding to Mitscherlich curve.

A significant enhancement in dry matter yield of maize was observed in the range of 9.80 g pot $^{-1}$ to 11.0 g pot^{-1} with application of 20 tonnes FYM ha $^{-1}$ thus indicating an increase of about 11.2 % irrespective of Cd (Table 4). This was the consequence and out come of the addition of FYM which increased organically bound, oxide bound and residual cadmium but decreased the exchangeable + water soluble and carbonate bound cadmium probably due to increase in soil organic carbon, electrical conductivity and available phosphorus in soils treated with FYM. These observations are in line with those of Ibrahim *et al.* (2010) and Iwegbue *et al.* (2007). Narwal and Singh (1998) observed that application of cow and pig manure decreased the exchangeable and water soluble cadmium in soils. Iwegbue *et al.* (2007) suggested that the organic compounds bound more trace metals than held on the exchange sites. The plant appeared healthier in all the FYM treated pots throughout the growing season. Similar effects of compost on growth media has been found in other studies (Atiyeh, 2001; Perez Murcia *et al.,* 2006) which were due to the improvement of soil structure by increasing porosity, water holding capacity and aeration.

Mean Cd concentration in maize increased successively with increasing cadmium application rates. Cadmium concentration in maize plant at 0, 10, 20 and 40 mg kg^{-1}soil applied Cd was 2.67, 10.33, 21.67 and 40.00 µg g^{-1} respectively (Table 4). This was probably due to significant increase in exchangeable + water soluble Cd with the increasing rates of Cd application which resulted an increased amount of metal being absorbed by the plants. Narwal *et al.* (1993), Sidhu and Khurana (2010) and Moustakas *et al*. (2011) also reported higher Cd content in maize, raya, spinach and marigold due to Cd application.

The toxic or upper critical level of Cd is defined as its lowest concentration in tissue or soil at which its presence led to reduction in yield. The critical concentration can be calculated by interpolating the concentration at which yield is reduced by some arbitrary amount usually 10 to 30 percent. For finding the upper critical level, the regression equations were worked out where the value of percent reduction in dry matter yield was regressed with corresponding plant Cd. Regression models were employed using MS excel (Windows 2007) to find out the best fit for establishing the critical level. Quadratic model seems to give the best description of the process as revealed by significant coefficient of determination (R^2 = 0.97). From this model, the toxic level of Cd in shoots of maize at 45 days growth stage at which 20 % reduction in dry matter yield occurred was estimated to be 8.8µg g^{-1} dry matter.

This toxic level was found to be within the range proposed by different workers. Phytotoxicity values and 3–20 µg g^{-1} (Singh and Nayyar, 1994; Sidhu and Khurana, 2010) have been reported for Cd for different crops. This suggests that plants growing in contaminated soil do not take up Cd in amounts exceeding the phototoxic level, the yields as a rule do not decrease. Further available reports showed marked differences for the Cd tolerance in wheat (Zhang *et al.*, 2002), cotton (Wu *et al.*, 2004), pea (Metwally *et al*., 2005). No visible toxicity symptoms were observed on the leaves of maize in this study up to an application rate of 10 mg kg^{-1} soil, thus illustrating that the metal may accumulate in maize upto 10.3 µg g^{-1} without visual evidence of its presence.

Organic fertilization also significantly influenced the value of Cd bioaccumulation (Table 4). The concentration of Cd in shoot with FYM treated soils decreased from 21.67 to 17.0 at 20 mg Cd kg^{-1} soil and from 40 to 35.5µg g^{-1} dry matter at 40 mg Cd kg^{-1} soil which was 21.5 and 11.5 % lower than that in control plants, respectively. As explained earlier, application of FYM had depressed the availability of Cd and increased the dry matter yield, thereby reduce the Cd concentration in maize plant observed. Moreover, reaction of organic matter constituents with

Table 3 : Sequential extraction method used for Cd fractions

Sr. No.	Fractions	Solution	Soil (g)	Solution (ml)	Conditions
1	Exchangeable + Water soluble (EX+WS)	1 M $Mg(NO_3)_2$	5	20	Shake 2 hrs at 25°C
2	Carbonates (CARB)	1 M NaOAC (pH 5.0 CH_3COOH)	5	20	Shake 3 hrs at 25°C
3	Organically bound (OM)	0.7 M NaOCl (pH 8.5)	5	20	Shake 30 min in boiling water bath, stir occasionally, repeat extraction
4	Mn-Oxides bound (MnOX)	0.1 M $NH_2OH.HCl$Sol. in 0.01 M HNO_3 (pH 2.0)	5	25	Shake 30 min
5	Amorphous Iron Oxide bound (AFeOX)	0.25 M NH_2OH. HCl + 0.25 M HCl	5	25	Shake 30 min in boiling water bath, stir occasionally
6	Crystalline Fe-oxide bound (CFeOX)	0.2 M $(NH_4)_2C_2O_4$ + 0.2 M $H_2C_2O_4$ (pH 3.0) + 0.4 M ascorbic acid	5	25	30 min in boiling water bath, stir occasionally
7	Residue bound (RES)	10 ml conc. HF + 2 ml $HClO_4$ + 6 N conc. HCl in sequence	0.5	25	Sand bath, cool, boil gently and cool

Table 4 : Effect of cadmium and farm yard manure on dry matter yield, cadmium content and cadmium uptake of maizel

FYM rates	Rates of cadmium application (mg kg^{-1} soil)				
	0	10	20	40	Mean
			Dry Matter Yield (g pot^{-1})		
0	13.8	10.4	8.6	6.3	9.8
20	14.8	12	9.8	7.4	11
Mean	14.3	11.2	9.2	6.85	
CD(p =0.05) FYM 0.30, Cd 0.49, FYM XCd =70					
			Cadmium content (µg g^{-1})		
0	2.67	10.33	21.67	40.00	18.67
20	2.0	8.0	17.0	35.5	15.63
Mean	2.34	9.17	19.34	37.75	
CD(p =0.05) FYM 0.84, Cd 1.19, FYM XCd =1.69					
			Cadmium uptake (µg pot^{-1})		
0	36.9	107.7	187.8	251.9	146.1
20	29.6	95.6	167.2	268.1	137.9
Mean	33.2	101.7	177.5	255.7	

CD(p =0.05) FYM 11.1, Cd 15.7, FYM XCd =22.3

Cd provide fixation sink due to chelation reactions leaving lesser Cd immediately available for plant (Zaniewicz *et al.,* 2007; Shuman *et al.,* 2002). Lee *et al.* (2004) also observed a decrease in Cd content in wheat plant with compost application.

Mean Cd uptake by maize plant increased significantly with its increasing levels applied to the soil irrespective of FYM levels. The mean Cd uptake was 33.2, 101.7, 177.5 and 255.7 µg pot^{-1} at 0, 10, 20 and 40 mg kg^{-1} soil added Cd levels respectively(Table 4).

Compared with (control) approximately 5.3 fold increase in its uptake was observed by applying 20 mg Cd kg^{-1} soil thereby suggesting its readily absorption and translocation from roots to above ground plant parts. Raising the Cd level to 40 mg Cd kg^{-1} did not increase Cd uptake by maize to an extent similar to that observed with 20 mg Cd kg^{-1} application. On applying 40 mg Cd kg^{-1}only 1.44 times increase in Cd uptake was observed over that recorded at 20 mg kg^{-1} soil. This kind of Cd uptake pattern was consequence of both reduction in yield due to Cd toxicity and increased concentration of Cd at higher application rate as a reduction in yield was compensated by higher Cd absorption.

Among parameters controlling the concentration of Cd in soil, pH, $CaCO_3$ and organic matter and available phosphorus are probably important parameters (Ghafoor *et al.,* 2008). The results have been reported in table 5 only for these parameters and for some of the treatments in order to avoid repetition. Addition of FYM @ 20 tonnes ha^{-1} altered original properties of the soil. Soil pH, organic carbon, electrical conductivity and available phosphorus increased in soils treated with FYM (Ibrahim *et al.,* 2010). The increase in organic content was especially noticeable in soils. Addition of cadmium even at highest rate did not influence any soil property.

Table 5 : Effect of selected treatments on some physico-chemical charactertics of the soil

Treatments	Rate	pH	EC (dS m^{-1})*	OC(%)	$CaCO_3$(%)	Avail P
Cadmium	40 mg kg^{-1}	7.74	0.76	0.54	0.74	16.0
FYM	20 tonnes ha^{-1}	8.28	0.96	0.82	0.80	24.7
Control Soil	7.98	0.71	0.52	0.75	15.2	

*1:4 farm yard manure: water suspension

Exchangeable and water soluble (EX+WS-Cd) increased significantly with each increasing level of Cd. It increased from 0.05 to 9.92 mg Cd kg^{-1} when Cd application was increased from 0 to 40 mg kg^{-1}soil. Since coarse textured soil offered little resistance, due to low CEC, therefore the extractability of this fraction was high in these soils. Application of manure decreased the amount of the above fraction irrespective of Cd levels. It was decreased by 15.2 % over non FYM treatment (Table 6). Similar results were observed by Ibrahim *et al.* (2010) and Narwal and Singh (1998) with different organic amendments. The results of Shuman *et al.* (2002) showed that a decrease in phytotoxicity was attributed to redistribution of Cd from the water soluble and exchangeable fractions to the organic fraction, which decreased the plant availability and uptake of Cd. Carbonate bound fraction (CARB-Cd) increased from 0.21 to 8.37 mg kg^{-1} soil with change in Cd application from 0 to 40 mg kg^{-1} soil. Ghafoor *et al* (2008) observed that cadmium carbonate controlled the activity of cadmium in soils. Application of FYM, irrespective of Cd rates decreased significantly the amount of Cd in this fraction from 4.58, 4 to 3.56 mg kg^{-1}soil. These results indicated the usefulness of organic matter in retarding the release of Cd from CARB pool which is considered to be slowly available to plants (Ramos *et al.*, 1994). The interaction of FYM with Cd was found to be significant in influencing the extraction of Cd in this fraction.

Cadmium associated with oxides of manganese (MnOX-Cd) increased progressively from 0.19 to 1.53, 3.03 and 5.51 mg kg^{-1} soil when Cd was applied at 0, 10, 20 and 40 mg kg^{-1} soil respectively. Application of FYM also showed significant positive effect. This fraction increased from 2.20 mg kg^{-1} soil in the absence of any FYM to 2.93 mg kg^{-1} soil showing an increase of approximately 33.0. The increase in MnOX -Cd with FYM addition might be due to the contribution of inherent metal present in FYM to the total content of the soil as FYM supplied a total content of 182 mg Mn kg^{-1} FYM. Bell *et al.* (1991) indicated that the content of MnOx-Cd in soils was governed by the total content of this metal in sludge and its rate of application.Organic bound fraction (OM-Cd) exhibited steady increase from 0.09 to 1.11, 2.52 and 4.40 gm Cd kg^{-1} when Cd was applied respectively at 0, 10, 20 and 40 mg kg^{-1} soil (Table 6) Ahmad *et al. (2008)* also observed that application of FYM @ 15g FYM kg^{-1} soil increased Cd and Pb concentration in organic bound fractions in sandy loam soil. Application of FYM registered an increase of 28 per cent. The increase due to FYM was probably due to addition of both organic carbon (16.78 percent) and inherent Cd present (0.37 mg kg^{-1} FYM) in FYM. Jalali and Arfania (2011) reported that in sewage irrigated soil , major portion of Cd was associated with organic matter. The interaction of FYM with Cd was found to be significant in all the soils. The combined addition of the FYM and Cd increased the content of this fraction from 3.98 mg kg^{-1} soil (F_0Cd_{40}) to 4.82 ($F_{20}Cd_{40}$).

Like other forms, consistent increasing trend was observed in amorphous Fe oxide bound fraction (A FeOX-Cd) with Cd application in this fraction. The comparatively higher amount of Cd in this fraction compared to other forms indicated that Cd might be specifically adsorbed on the Fe-Mn oxide or incorporated inside the oxide particles (Li *et al.,* 2007).

Application of FYM encouraged Cd to be accumulated more in this fraction. Application of FYM @ 20 tonnes ha^{-1} increased the mean content of this fraction from 3.27 to 3.73 mg kg^{-1} soil. Since FYM additions resulted in an increase in soil pH, organic carbon, electrical conductivity and available phosphorus which might have transformed the available fractions to relatively unavailable forms. These results find support from the work of Ibrahim *et al.* (2010) who reported that conversion of soluble/ exchangeable Cu and Cd to other insoluble forms after the application of organic amendments may be ascribed to the increases of soil OM, pH, EC, and available P contents Cadmium in crystalline Fe-oxide (C FeOX-Cd) pool showed an increasing trend with Cd rates but decreasing trend due to the application of FYM. The amount of this fraction was 31 % more in non FYM treated soils in comparison to 20 tonnes ha^{-1} FYM treated soils. Residual fraction (RES-Cd**) :** Cadmium rates influenced this pool(RES-Cd**)** positively whereas no effect was observed with applied FYM.

Fractionation result (Table 6) revealed that all the fraction exhibited increase with Cd rates but addition of FYM increased organically Cd (OM-Cd), all oxide bound fractions (MnOX-Cd, A FeOX-Cd, C FeOX-Cd) and RES-Cd but decreased the (EX+WS-Cd) and CARB-Cd. Cadmium present in the exchangeable + water soluble fraction is considered readily available, organically bound and carbonate bound fractions are considered slowly available and oxide bound and residual fractions are relatively unavailable to plants, thereby mitigating the toxic effect of Cd as evidenced by increase in dry matter yield, decrease in plant Cd and its uptake.

Table 6 : Effect of cadmium and farm yard manure on various fractions (mg kg^{-1} soil)

FYM rates	**Rates of cadmium application (mg kg^{-1} soil)**				
	0	10	20	40	Mean
		Exchangeable and water soluble cadmium			
0	0.03	3.00	4.60	10.34	4.49
20	0.06	2.29	3.40	9.50	3.81
Mean	0.05	2.65	4.0	9.92	
CD(p =0.05) FYM 0.16, Cd 0.28, FYM XCd =0.33					
		Carbonate bound cadmium (mg kg^{-1} soil)			
0	0.22	3.42	5.42	9.24	4.58
20	0.20	2.45	4.10	7.50	3.56
Mean	0.21	2.94	4.76	8.37	
CD (p=0.05) FYM=0.34 Cd=0.48 FYMXCd =0.68					
		Mn oxide bound cadmium (mg kg^{-1} soil)			
0	0.180	1.35	2.66	4.62	2.20
20	0.200	1.70	3.40	6.40	2.93
Mean	0.19	1.53	3.03	5.51	
CD (p=0.05) FYM=0.08 Cd=0.10 FYMXCd =0.14					
		Organic bound cadmium (mg kg^{-1} soil)			
0	0.08	0.92	2.14	3.98	1.78
20	0.10	1.30	2.89	4.82	2.28
Mean	0.09	1.11	2.52	4.40	
CD (p=0.05) FYM=0.19 Cd=0.37 FYMXCd =0.57					
		Amorphous Fe oxide bound cadmium (mg kg^{-1} soil)			
0	0.34	1.60	2.45	7.68	3.27
20	0.36	2.14	4.13	8.27	3.73
Mean	0.35	1.87	3.29	7.98	
CD (p=0.05) FYM =0.12 Cd=0.17 FYMXCd =0.23					
		Crystalline Fe oxide bound cadmium (mg kg^{-1} soil)			
0	0.12	0.68	1.50	2.38	
20	0.10	0.40	0.94	1.64	
Mean	0.11	0.54	1.22	2.07	
CD (p=0.05) FYM =0.06 Cd=0.08 FYMXCd =0.11					
		Residual cadmium (mg kg^{-1} soil)			
0	0.58	1.02	2.10	3.45	1.79
20	0.52	0.94	2.0	3.36	1.71
Mean	0.55	0.98	2.05	3.45	
CD (P=0.05) FYM =NS Cd=0.10 FYMXCd =NS					

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