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Original Research Paper

Remediation of Phytotoxic Effect of Chromium by Different Amendments in Rice-Wheat Sequence

J. K. Parmar and K. P. Patel
Department of Agricultural Chemistry and Soil Science, Anand Agricultural University, Anand, Gujarat

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ABSTRACT

A pot-house experiment was carried out at Micronutrient Project, AAU, Anand to study the effect of Cr levels (0, 10, 20, 40, 80 and 160 mg/kg soil) in presence and absence of amendments (FYM and gypsum) on rice and wheat under rice-wheat sequences on coarse loamy soil with three replications under factorial completely randomized block design. The experimental results indicated the rice grain yield gradually decreased due to direct effect of Cr while residual effect was found beneficial up to Cr20 which improved grain yield of wheat by 15.09 per cent over control. Similarly, rice and wheat grain as well as straw yield were also found enhanced due to direct and residual effect of FYM and gypsum over their corresponding control. The Cr content in grain and straw of rice and wheat significantly increased with increase in Cr levels due to both direct and residual effect of Cr. The highest Cr content was recorded in straw followed by grain in both the crops. The application of farm yard manure (FYM) and gypsum significantly decreased Cr content of rice and wheat grain and straw due to direct and residual effect. The direct and residual effect of gypsum and FYM decreased Cr content of rice grain by 21.31 and 28.30 per cent over corresponding control. The Cr application increased DTPA-Cr of the soil due to direct and residual effect after rice and wheat. The application of amendments significantly decreased DTPA-Cr in the soil after both rice and wheat in the soil over control. The findings, in general, indicated that the toxic effect of Cr on crop could be mitigated more effectively with FYM application and reduce risk of health hazards for human beings and animals. However, the regular monitoring for soil quality is necessary for managing Cr pollution in the soil.

INTRODUCTION

In different parts of the country, the menace of rapidly increasing population, the want on growth of industries and increasing urbanization has created major problems with the disposal of sewage and industrial effluents. In recent years, contamination of the environment by Cr, especially hexavalent Cr, has become a major area of concern. Chromium has many applications in modern industry. Its production and industrial applications have resulted in large quantities of this element being discharged into the atmosphere, soil, surface water and groundwater resulting in significant environmental contamination. Chandra et al. (1997) estimated that in India alone about 2000 to 3200 tones of elemental Cr escape into the environment annually from the tanning industries, with a Cr concentration ranging between 2000 and 5000 mg/L in the effluent compared to the recommended permissible limit of 2 mg/L.

The main source of irrigation in Nawagam area is open well, bore well and village ponds. The village ponds receive effluent water through Khari canal/channel, which carries industrial effluents discharged from the industrial area of Naroda and Vatva. These effluents may or may not be biodegradable. There are approximately 525 units generating effluents having Cr content, which contaminate the surface and groundwater and soils of the area by chromium. Farmers in Nawagam area use effluent diluted with fresh canal water for irrigation purpose as and when required. In addition, water tube well of nearby effluent canal is contaminated and being used for irrigating in rice-wheat sequence. However, information is hardly available on the phytotoxicity of Cr. So, the pot experiment was taken for the study of toxic effects of Cr with amendments viz., FYM and gypsum to offset the adverse effects of Cr on the growing rice-wheat sequence on soils of Nawagam area.

MATERIALS AND METHODS

The experiment was conducted in a pothouse of the Micronutrient Project (Indian Council of Agricultural Research), Anand Agricultural University, Anand during 2005-06 *rabi* and summer seasons to study the effect of different levels of Cr with and without amendments on rice-wheat sequence. The three levels of amendments (No amendment (Am_0), 1.0 % FYM (Am_1) and gypsum at 50 % of gypsum requirement (GR) (Am_2) and six levels of chromium (0, 10, 20, 40, 80, 160 mg/kg soil) were tested under factorial randomized block design. The bulk surface soil samples (0-15 cm), belonging to Typic Ustochrepts were collected from tube well water irrigated farmers' fields of Nawagam-Vatava region. The initial characteristics of experimental soils were: texture-sandy loam, pH 8.23, EC 0.36 dSm^{-1}, organic carbon 0.38 per cent; and the Olsen' P, ammonium acetate extractable K and heat soluble sulphur were 24.51, 376, and 14.21 mg/kg soil, respectively. All the pots received uniform dose of 120 kg N and 60 kg P_2O_5 ha^{-1}, respectively.

The five kg of soil was treated with required amount of Cr through potassium dichromate ($K_2Cr_2O_7$) i.e. Cr(VI), gypsum and farmyard manure (FYM). After thorough mixing, the soil was filled in the earthen pots of 6 kg capacity. The sowing was done after pots were incubated and watered at field capacity. The crop was grown up to maturity. After harvest of the crop, plant (grain and straw, separately) samples were collected from each pot and washed successively with tap water and thereafter with single and double distilled water, oven dried at 65°C and grinded in Willy mill to pass through 0.5 mm screen. The plant samples were digested in a di-acid mixture of HNO_3 and $HClO_4$. The chromium from grain and straw samples was determined by atomic absorption spectroscopy method given by Jackson (1973). Soil samples were taken after harvest of wheat from each pot with the help of stainless steel tube auger. The samples were dried, grinded and passed through 2 mm sieve and stored in a polythene lined cloth bag for chemical analysis. The pH, EC (1:2.5 - soil:water, Jackson 1973), organic carbon (Walkley & Black 1934) and DTPA-Cr (Lindsay & Norvell 1978) were determined by standard procedures.

RESULT AND DISCUSSION

Effect of chromium on yield of rice and wheat (rice-wheat sequence): The direct effect of Cr showed adverse effect on rice grain yield and gradually decreased to the lowest value at Cr160 with reduction in the yield by 19.9 per cent over control (27.6 g/pot). In case of residual effect of Cr on wheat, there was a significant improvement (15.1 per cent) up to Cr20 and at higher levels it showed depressing effect which caused minimum grain yield at Cr160 level with a reduction of 39.6 per cent over control (5.3 g/pot) (Table 1). It clearly showed that rice is more tolerant pant than the wheat.

Similar results were also found in straw yield of rice and wheat due to direct as well as residual effect of Cr, respectively (Table 2). The direct application of Cr increased rice straw yield by 2.8 per cent over control at Cr20 level. While, the highest reduction in rice straw yield due to direct effect was observed at Cr160 by 8.6 per cent over corresponding control (29.0 g/pot). The improvement in wheat straw yield was noted up to Cr10 due to residual effect. The reduction in wheat straw yield due to residual (Cr160) effect of Cr was by 21.2 per cent over control (Table 1). The beneficial effect of Cr at lower level up to Cr10 or Cr20 on rice and wheat could be attributed to increased absorption of nutrients like K, Ca and Mg, while at higher Cr it might have adversely affected due to phytotoxicity. The Cr is inhibitory to metabolism and acts on a contributory factor in phytotoxicity of wheat (Sharma et al. 1995). Several workers have reported similar results in different plants viz., peas (Bishnoi et al. 1993), wheat (Sharma & Sharma 1993) and spinach (Anon 2003).

Effect of amendment on yield of rice and wheat (rice-wheat sequence): The rice grain yield was also found enhanced due to direct effect of both the amendments FYM and gypsum over control by 11.5 and 8.5 per cent, respectively. The residual effect of the amendments was also found to be beneficial which increase wheat grain yield due to both FYM and gypsum by 16.3 per cent over control (Table 1). Similar results were observed in straw yield of wheat due to direct and residual effect of amendments (Table 2). The improvement in yield of both rice and wheat could be attributed to addition of amendment viz., FYM and gypsum to the soil, which increased the availability of nutrients due to improvement in important soil properties (Ganal & Singh 1988, Singarum 1994). Similarly, Rao & Shantaram (1996) also observed increase in maize yield due to FYM application.

Interaction effect of Cr × Am on yield of rice and wheat (rice-wheat sequence): The interaction effect of Cr and amendments indicated that the adverse effect of Cr on yield of rice and wheat could be alleviated to some extent by amendment application especially with FYM addition. Significantly, the highest rice grain yield was recorded at Cr0 with FYM; while the maximum yield reduction was noted by 28.7 per cent over control at Cr160 level without amendment (Table 1). The interaction effect for Cr × Am on wheat grain yield caused significant increase at Cr20 when applied together with FYM over absolute control (Table 1). The improvement in wheat grain yield due to residual effect of Cr20 with FYM was by 23.6 per cent over control. The beneficial effect of amendments could also be ascribed to increased microbial activity which might have helped in reduction of toxic form (Cr^{6+}) to non toxic form (Cr^{3+}) by microbial activity, by acting as electron donors, and by lowering the O_2 level of the soil thereby creating reducing conditions. Almost similar trend was noticed for straw yield of rice and wheat as influence by direct and residual effect of Cr as well as interaction effect of Cr × Am (Table 2). Similar results have also been reported by Losi et al. *(*1994) Bolan et al. (2003) Yuji et al. (2004).

Effect of chromium on Cr content in grain and straw of rice and wheat (rice-wheat sequence): The data on Cr con-

Table 1: Effect of Cr and amendments on grain yield of rice and wheat (rice-wheat sequence).

	Cr Levels	(Grain yield (g/pot)) Rice (Direct effect)				Wheat (Residual Effect)			
		Am0	Am1	Am2	Mean	Am0	Am1	Am2	Mean
	Am levels	No Am	FYM	GYP		No Am	FYM	GYP	
1.	Cr0	26.5	29.2	27.2	27.6	5.5	5.2	5.2	5.3
2.	Cr10	26.4	28.0	27.5	27.3	5.9	5.5	5.7	5.7
3.	Cr20	25.2	26.1	25.5	25.6	4.9	6.8	6.6	6.1
4.	Cr40	24.1	25.4	25.1	24.9	3.7	4.6	4.8	4.4
5.	Cr80	20.0	24.7	24.3	23.0	2.8	4.4	4.2	3.8
6.	Cr160	18.9	24.0	23.4	22.1	2.8	3.6	3.3	3.2
	Mean	23.5	26.2	25.5	25.1	4.3	5.0	5.0	4.8
			Am	Cr	Am×Cr		Am	Cr	AmxCr
	SE.m±		0.2	0.3	0.4		0.1	0.2	0.3
	CD at 5%		0.5	0.8	1.1		0.4	0.7	1.0
	CV %		2.7				12.6		

Table 2: Effect of Cr and amendments on straw yield of rice and wheat (rice-wheat sequence).

	Cr Levels	Straw yield (g/pot) Rice (Direct effect)				Wheat (Residual effect)			
		Am0	Am1	Am2	Mean	Am0	Am1	Am2	Mean
	Am levels	No Am	FYM	GYP		No Am	FYM	GYP	
1.	Cr0	29.2	29.0	28.8	29.0	9.0	8.7	8.8	8.5
2.	Cr10	29.3	30.4	29.5	29.7	8.8	8.2	8.3	8.8
3.	Cr20	28.6	30.6	30.0	29.8	7.5	8.2	8.2	8.0
4.	Cr40	26.9	28.7	27.8	27.8	6.4	7.9	8.1	7.5
5.	Cr80	26.7	27.3	27.1	27.0	6.3	6.6	8.0	7.0
6.	Cr160	25.8	26.8	26.8	26.5	5.9	6.5	7.7	6.7
	Mean	27.8	28.8	28.3	28.3	7.3	7.7	8.2	7.7
			Am	Cr	Am×Cr		Am	Cr	AmxCr
	SE.m±		0.2	0.4	0.5		0.04	0.1	0.1
	CD at 5%		0.6	1.1	NS		0.1	0.2	0.3
	CV %		3.2				2.7		

Table 3: Effect of Cr and amendments on Cr content in grain of rice and wheat (rice-wheat sequence).

	Cr Levels	Cr (μg/g) Rice (Direct effect)				Wheat (Residual effect)			
		Am0	Am1	Am2	Mean	Am0	Am1	Am2	Mean
	Am levels	No Am	FYM	GYP		No Am	FYM	GYP	
1.	Cr0	0.62	0.58	0.43	0.54	0.60	0.44	0.48	0.50
2.	Cr10	2.40	2.19	2.37	2.32	1.08	0.55	0.78	0.81
3.	Cr20	4.03	2.43	3.83	3.43	2.20	1.80	2.13	2.04
4.	Cr40	6.17	5.47	5.87	5.83	2.77	2.20	2.80	2.59
5.	Cr80	7.79	5.75	6.45	6.66	3.33	2.28	3.15	2.92
6.	Cr160	8.25	6.60	7.04	7.30	4.62	3.12	3.19	3.64
	Mean	4.88	3.84	4.33	4.35	2.43	1.73	2.09	2.08
			Am	Cr	Am×Cr		Am	Cr	AmxCr
	SE.m±		0.08	0.14	0.19		0.19	0.33	0.47
	CD at 5%		0.23	0.39	0.50		0.55	0.95	NS
	CV %		7.69				38.91		

tent in grain and straw of rice and wheat are presented in Table 3 and 4, respectively. The Cr application significantly increased Cr content of rice grain and straw with increase in Cr levels (Figs. 1 and 3). The highest Cr content of grain (7.30 μg/g) and straw (4.71 μg/g) of rice were noted due to direct effect of Cr at Cr160 level which was 13.5 and 5.5 times higher over corresponding control. The residual effect of Cr also significantly increased Cr content of wheat

Table 4: Effect of Cr and amendments on Cr content in straw of rice and wheat (rice-wheat sequence).

	Cr Levels	Cr (μg/g) Rice (Direct effect)				Wheat (Residual effect)			
		Am0	Am1	Am2	Mean	Am0	Am1	Am2	Mean
	Am levels	No Am	FYM	GYP		No Am	FYM	GYP	
1.	Cr0	0.87	1.48	0.22	0.86	0.58	0.20	0.50	0.43
2.	Cr10	1.67	1.92	0.77	1.45	1.24	0.30	1.62	1.05
3.	Cr20	4.30	2.27	1.00	2.52	2.52	0.48	1.57	1.52
4.	Cr40	4.52	2.55	1.60	2.89	4.15	0.70	0.58	1.81
5.	Cr80	6.82	3.03	2.15	4.00	4.33	0.83	2.86	2.67
6.	Cr160	6.85	3.78	3.48	4.71	6.27	1.84	3.82	3.98
	Mean	4.17	2.51	1.54	2.74	3.18	0.73	1.82	1.91
			Am	Cr	Am×Cr		Am	Cr	AmxCr
	SE.m±		0.03	0.05	0.07		0.06	0.10	0.15
	CD at 5%		0.08	0.15	0.21		0.17	0.30	0.42
	CV %			4.55			13.38		

Table 5: Effect of Cr and amendments on DTPA-Cr contents after rice and wheat (rice-wheat sequence).

	Cr Levels	Cr (μg/g) Rice (Direct effect)				Wheat (Residual effect)			
		Am0	Am1	Am2	Mean	Am0	Am1	Am2	Mean
	Am levels	No Am	FYM	GYP		No Am	FYM	GYP	
1.	Cr0	0.08	0.20	0.24	0.17	0.07	0.18	0.21	0.15
2.	Cr10	3.62	2.57	2.33	2.84	0.82	0.69	0.49	0.67
3.	Cr20	5.17	4.44	4.89	4.84	1.21	0.73	0.81	0.92
4.	Cr40	8.32	8.27	8.18	8.26	1.56	0.81	0.91	1.10
5.	Cr80	13.82	12.27	12.24	12.78	1.79	0.93	1.16	1.29
6.	Cr160	19.45	17.48	18.36	18.43	2.01	1.91	1.65	1.86
	Mean	8.41	7.54	7.71	7.89	1.25	0.87	0.87	1.00
			Am	Cr	Am×Cr		Am	Cr	AmxCr
	SE.m±		0.17	0.29	0.41		0.02	0.04	0.05
	CD at 5%		0.48	0.83	NS		0.06	0.11	0.16
	CV %			9.00			9.18		

grain and straw with increase in Cr levels (Figs. 2 and 4). The highest Cr content of grain (3.64 μg/g), straw (3.98 μg/g) were recorded at the highest level of Cr i.e., Cr160. This could be mainly due to higher addition of Cr in soil, which in turn increased DTPA-Cr in the soil. Similar effect was also noted by Bolan et al. (2003), Kabata-Pendias & Pendias (2001) and Bishnoi et al. (1993).

Effect of amendment on Cr content in grain and straw of rice and wheat (rice-wheat sequence): The direct effect of FYM and gypsum significantly decreased the adverse effect of toxicity of Cr content in different parts of rice; the direct application of FYM was more effective for decreasing Cr content of grain of rice by 21.3 per cent over control. Similarly, gypsum was also found more effective to decrease Cr content of rice straw by 63.1 per cent over control. Similarly, the residual effect of FYM significantly lowered Cr content of grain and straw of wheat by 28.8 and 77.0 per cent over control, respectively (Figs.1 and 3).

The overall results indicated that the direct and residual effect of amendment significantly decreased Cr content in grain and straw of rice and wheat over control. These might be due to application of organic matter and plant root exudates, which contained various organic acids like humic acid, fulvic acid, etc. The organic acids could reduce and immobilize Cr and might form organic compounds originated from turn over of bacterial activities to make reduction of Cr (Deng & Stone 1996). The incorporation of FYM is expected to mitigate the adverse effect of Cr due to its fixation with colloidal particles present in organic matter.

Effect of Cr × Am interaction on Cr content of rice and wheat (rice-wheat sequence): The Cr content of rice grain and straw was significantly increased with Cr levels with and without amendment (Table 3). The application of FYM with Cr decreased Cr content of grain in corresponding level of Cr. Similarly, direct effect of gypsum with Cr decreased Cr content of straw. The residual effect of Cr × Am interac-

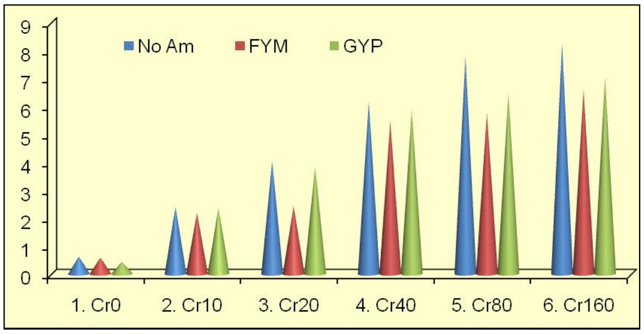

Fig. 1: Effect of Cr and amedments on Cr content in grain of rice.

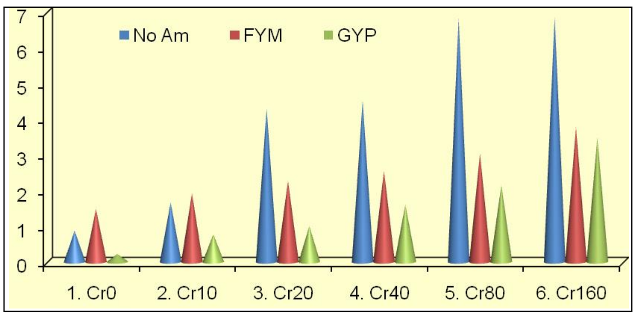

Fig. 3: Effect of Cr and amedments on Cr content in straw of rice.

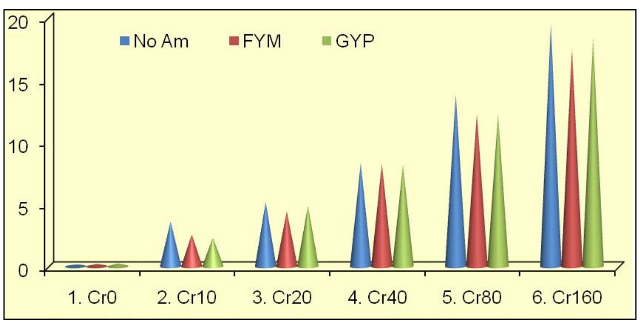

Fig. 5: Effect of Cr and amedments on DTPA Cr contents after rice.

tion significantly changed Cr content in straw of wheat, while Cr content of grain was found non-significant (Tables 3 and 4). The Cr content of wheat straw was increased with increase in Cr levels with and without amendments (Figs. 2 and 4). However, the application of Cr levels with amendments decreased Cr content of grain and straw of wheat as compared to alone application of Cr (Tables 3 and 4).

Further, the effect of FYM was more pronounced in Cr content of straw. The maximum Cr content in wheat straw was found at Cr160 level when applied alone. These results might be ascribed to organic matter which expected to enhance the reduction of chromate in soil. Similarly, the use of organic materials could reduce the desorption of metals in soil due to formation of various insoluble compounds (Ram & Verloo 1985, Mengel & Kirkby 1987, Narwal et al. 1992).

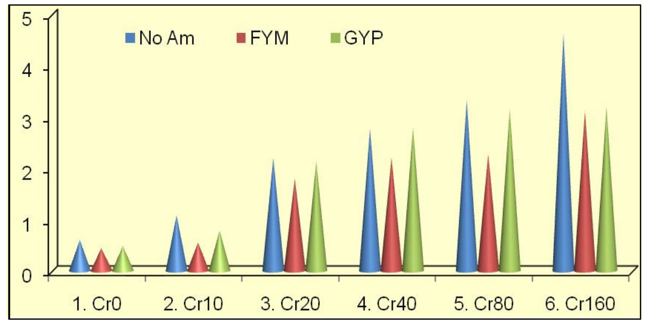

Fig. 2: Residual effect of Cr and amedments on Cr content in grain of wheat.

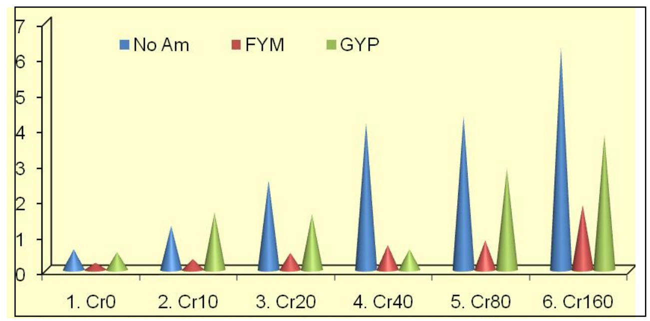

Fig. 4: Residual effect of Cr and amedments on Cr content in straw of wheat.

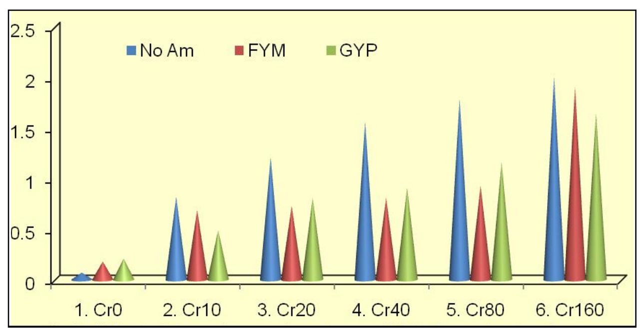

Fig. 6: Effect of Cr and amedments on DTPA Cr contents after rice-wheat cropping sequence.

Effect of Cr on DTPA-Cr after rice and rice-wheat sequence: The data on Cr status of soil after rice indicated that DTPA-Cr after rice increased with increase in Cr levels (Table 5). The highest Cr content (18.43 μg/g) was noted in cr160. Similar, results was also found after the rice-wheat sequence. The residual effect of levels caused increase in DTPA-Cr being maximum in Cr160 (1.86 μg/g) over control (0.15 μg/g) (Fig. 6). The status of Cr after rice-wheat was lower down in respective level as compared to Cr status after rice. This may indicate that the applied Cr was heavily uptake by rice and wheat (Chandra et al. 1997). The remaining Cr was distributed among different factions of Cr (Bolan et al. 2003)

Effect of amendments on DTPA-Cr after rice and rice-wheat sequence: The DTPA-Cr was found decreased significantly by 10.34 and 8.32 per cent over control (8.41 µg/g) due to direct effect of FYM and gypsum application to rice. Similar effects were also noticed after rice-wheat sequence (Table 5). The overall results on DTPA-Cr changes in soil after rice-wheat, the significant decrease in DTPA-Cr could be ascribed to organic material which reduced the desorption of heavy metals in soil due to formation of various insoluble compounds. Ram & Verloo (1985), Mengel & Kirkby (1987) and Narwal et al. (1992) reported that DTPA-Cr was decreased with increasing rate of organic matter application.

Interaction effect of amendments on DTPA-Cr after rice and rice-wheat sequence: The interaction effect was found significant which indicated that highest level of Cr applied alone showed highest status of DTPA-Cr (19.45 mg/kg), while lowest Cr status of 0.08 mg/kg was noted with absolute control (Fig. 5). It was noted that application of Cr alone caused higher value of DTPA-Cr over FYM and gypsum in respective level of Cr. The addition of amendments combined with Cr levels decreased DTPA-Cr as compared to Cr application alone (Table 5, Fig. 5). Similarly, residual effect of Cr was significant which increased DTPA-Cr after wheat also. The interaction effects indicated that the application of 80 mg/kg Cr with FYM and 160 mg/kg Cr with gypsum were significantly at par with 40 mg/kg Cr applied alone, respectively (Table 5). The highest Cr content (2.01 µg/g) was noted with 160 mg/kg applied alone while minimum Cr (0.07 µg/g) was noted in absolute control, respectively.

The results, in general, indicted that the application of Cr increased DTPA-Cr content of soil after each crop over corresponding control. However, with addition of amendments, especially FYM the DTPA-Cr, status could be decreased more than that was noticed due to Cr application alone. Similar observation was made for different heavy metals in soil after spinach (Anon 2003).

CONCLUSIONS

The findings clearly showed adverse effect of Cr on yield of rice and wheat grown under rice-wheat sequences. The rice was found comparatively more tolerant to Cr than wheat. The translocation of Cr towards grain at higher levels was also high, which indicated possible concern for the health over the time, if the produce is utilized for food consumption. The risk of possible health hazards could be reduced with application of FYM to some extent in such high Cr containing soils. However, as such the soils contaminated with heavy metals need regular monitoring in view of their safe use in agriculture.

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