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Role of Organic Amendments to Improve Chemical Properties of Chromium Contaminated Alluvial Soil of Varanasi, Uttar Pradesh, India

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ABSTRACT

Two experiments in pot were conducted in net house during 2015-16 and 2016-17 to assess the efficiency of some organic amendments to improve the chemical properties (Organic carbon, EC, pH, DTPA extractable Cr and nutrients content) of chromium contaminated soils. Five chromium levels with and without organic amendments (vermicompost, farm yard manure and sewage sludge), were applied. Soil dried in shade was ground to sieve by 2 mm and homogenized. 0, 20, 40, 60 and 80 mg/kg doses of chromium and three organic amendments viz., vermicompost (VC) @ 5 t/ha, farm yard manure (FYM) @ 10 t/ha and sewage sludge (Sl) @ 20 t/ha were used. Total 20 treatments viz., T_1: Control, T_2: 20 ppm Cr, T_3: 40 ppm Cr, T_4: 60 ppm Cr, T_5: 80 ppm Cr, T_6: 0 ppm Cr + Sl, T_7: 20 ppm Cr + Sl, T_8: 40 ppm Cr + Sl, T_9: 60 ppm Cr + Sl, T_{10}: 80 ppm Cr + Sl, T_{11}: 0 ppm Cr + FYM, T_{12}: 20 ppm Cr + FYM, T_{13}: 40 ppm Cr + FYM, T_{14}: 60 ppm Cr + FYM, T_{15}: 80 ppm Cr + FYM, T_{16}: 0 ppm Cr + VC, T_{17}: 20 ppm Cr + VC, T_{18}: 40 ppm Cr + VC, T_{19}: 60 ppm Cr + VC and T_{20}: 80 ppm Cr + VC were taken. Results obtained from experiments elaborated that adding of organic amendments significantly improved the organic carbon and nutrients content of soil in comparison with the respective chromium treatment, DTPA extractable Cr in soil significantly decreased with organic amendments. Maximum improvement in chemical properties was reported with the applying vermicompost @ 5 ton/ha over control. FYM and sewage sludge were also found significantly higher over respective chromium treatments. However the improvement in pH and EC was non-significant.

Keywords Chemical properties of soil, Chromium, Nutrients content, Organic amendments.

INTRODUCTION

The contamination of the soil milieu with chromium compounds is more and more frequently occurring problem throughout the world (Radziemska and Wyszkowski 2017b) and the average content of chromium in soils around the world is 54 mg/kg (Radziemska and Wyszkowski 2017a). Chromium

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pollution of soil and water is a severe ecological concern owing to its possible carcinogenicity in the form of hexavalent chromium (Cr (VI)) upon ingestion (Choudhary *et al.* 2017). Chromium can hamper with the plant's mineral nutrition in a multifarious fashion because it is structurally analogous with some essential elements (Kant *et al.* 2018a). Utmost attention has received by researchers for the influences of Cr with uptake and accumulation of other mineral nutrients (Kumar *et al.* 2016). Many complex processes like ionic exchange, precipitation on surface and stable compounds formation with organic ligands are involved in immobilization by the amendments (Kumar *et al.* 2020). For metals immobilization in the soils, organic and inorganic materials as amendments can be used with a number of benefits but amendments of organic nature might be the better preference owing to the capacity of organic amendments to improve physical, chemical, biological properties and fertility status of the soil (Kant *et al*. 2018b). Several organic amendments can reduce the bioavailability, solubility as well as leaching of trace elements (Kumar *et al.* 2018b). Microbial activity and soil fertility may be improved by organic amendments, leading to the amendment of the soil quality as a whole (Kumar and Sharma 2018). These may be organic or green manure, crop residues, wastes from rural areas, vermicompost and biofertilizers (Kumar *et al.* 2018b). The positive and beneficial response of vermicompost on soil characteristics, growth and yield of crop is well known and proven (Kumar *et al.* 2018a, 2017a, 2017b). Very limited comparative studies have been executed for the selection of a specific organic amendment in aided phytostabilization approaches (Hattab *et al*. 2015). We made an attempt to assess the comparative efficiency of sewage sludge, farmyard manure and vermicompost on chemical properties of chromium contaminated post-harvest soil.

MATERIALS AND METHODS

Two pot experiments have been taken in the net house during 2015-16 and 2016-17. Bulk of soil was taken from the Agricultural Research Farm, Institute of Agricultural Sciences. Soil was dried in shade, ground to sieve by 2 mm and homogenized. 0, 20, 40, 60 and 80 mg/kg doses of chromium and three organic amendments viz. vermicompost (VC) @ 5 t/ha, farm yard manure (FYM) @ 10 t/ha and sewage sludge (Sl) @ 20 t/ha were used. The experiment was placed in Completely Randomized Design (CRD) taking 20 treatments viz., T_1: Control, T_2: 20 ppm Cr, T_3: 40 ppm Cr, T_4: 60 ppm Cr, T_5: 80 ppm Cr, T_6: 0 ppm Cr + Sl, T_7: 20 ppm Cr + Sl, T_8: 40 ppm Cr + Sl, T_9: 60 ppm Cr + Sl, T_{10}: 80 ppm Cr + Sl, T_{11}: 0 ppm Cr + FYM, T_{12}: 20 ppm Cr + FYM, T_{13}: 40 ppm Cr + FYM, T_{14}: 60 ppm Cr + FYM, T_{15}: 80 ppm Cr + FYM, T_{16}: 0 ppm Cr + VC, T_{17}: 20 ppm Cr + VC, T_{18}: 40 ppm Cr + VC, T_{19}: 60 ppm Cr + VC and T_{20}: 80 ppm Cr + VC. Aashirwad variety of mustard was used as test crop. N - P_2O_5 - K_2O and S were applied @ 90-60-40 and 40 kg ha^{-1} as through Ammonium Sulphate (AS), Single Super Phosphate (SSP) and Muriate Of Potash (MOP). For sulfur no separate fertilizer was used as the quantity of required sulfur was fulfilled through AS and SSP. Chromium (Cr as $K_2Cr_2O_7$) was applied in aqueous form and the soil was incubated for one month to maintain equilibrium before sowing.

DTPA extraction method of Lindsay and Norvell (1978) was used to determine available chromium. 10 g of soil was taken and extracted with 20 ml DTPA solution (0.005 M DTPA + 0.01M $CaCl_2.2H_2O$ + 0.1M TEA) by shaking for 2 hrs. The content was filtered and chromium was estimated with atomic absorption spectrophotometer (AAS) (Agilent Technologies 200 Series AA) using respective cathode lamps (Isaac and Kerber 1971) as per the procedure described by Singh *et al.* (2007). pH was measured in soil-water suspension of 1:2.5 ratio with pH meter (Sparks 1996). This soil water suspension was kept to get clear supernatant. EC meter was used to measured electrical conductivity as dS m^{-1} (Sparks 1996). Walkley and Black (1934) wet digestion method was used for organic carbon determination. For determination of available nitrogen in soil, Subbiah and Asija (1956) method was applied, available phosphorus was estimated by the method given by Olsen *et al.* (1954), estimation of available potassium was done by 1 N ammonium acetate extraction method given by Hanway and Heidal (1952) using flame photometer. Available sulfur was determined by the procedure given by Chesnin and Yein (1951). Available iron, copper, manganese and zinc in soil were estimated by the procedure of DTPA solution (0.005M DTPA + 0.01M $CaCl_2.2H_2O$ + 0.1M TEA) outlined by Lindsay and Norvell (1978) by atomic absorption spectrophotometer (Agilent Technologies 200 Series AA) using respective cathode lamps.

Statistical analysis was made for defining the significance among the treatment means and to draw an effective conclusion. The data observed during the entire experiment, was statistically analyzed by implementing appropriate method for "Analysis of Variance". The significance of treatment outcome was judged with the 'F' test. 1% probability level was used to compare the treatments mean for critical difference (Gomez and Gomez 1984) by following Complete Randomized Design (CRD).

RESULTS AND DISCUSSION

Effect of organic amendments and chromium on DTPA extractable chromium in soil

DTPA extractable chromium in soil before sowing of mustard

The data concerning with DTPA extractable chromium in soil is provided in Table 1 showed the significantly different values of DTPA extractable chromium in soil with application of organic amendments in chromium contaminated soils in both the years. DTPA extractable chromium in soil before sowing of crop varied from 0.31 to 67.47 and 0.29 to 65.54 mg/kg in 2015-16 and 2016-17 respectively. It was reported that treatment T_{16} (vermicompost @ 5 ton/ha) recorded lowest value 0.31 and 0.29 mg/kg of DTPA extractable chromium in soil during 2015-16 and 2016-17 as compare to rest of the treatments. However, application of farm yard manure @ 10 ton/ha (T_{11}) remains next treatment with 0.35 and 0.32 mg/kg DTPA extractable chromium in soil in 2015-16 and 2016-17, respectively which was at par with T_{16} (vermicompost @ 5 ton/ha). Furthermore, application of sewage sludge @ 20 ton/ha (T_6) recorded the lower DTPA extractable chromium in soil 0.39 and 0.35 mg/kg in 2015-16 and 2016-17, respectively as compared to control which found at par with T_{11} and T_{16}. Maximum value 67.47 and 65.54 mg/kg of DTPA extractable chromium in soil was observed in treatment T_5 (80 ppm chromium) during 2015-16 and 2016-17. We also noticed that DTPA extractable

Table 1. Effect of organic amendments on DTPA extractable chromium (mg/kg) (AAS) in chromium contaminated soils. Cr = Chromium, Sl = Sewage sludge, FYM = Farm yard manure, VC = Vermicompost, CD = Critical difference, SEm± = Standard error of mean, ND = Not detected.

Treatment		Pre sowing		Post-harvest soil	
		2015-16	2016-17	2015-16	2016-17
T_1	Control	0.40	0.37	ND	ND
T_2	20 ppm Cr	16.87	16.22	4.22	4.05
T_3	40 ppm Cr	33.73	32.44	8.43	8.11
T_4	60 ppm Cr	50.60	49.00	15.18	14.70
T_5	80 ppm Cr	67.47	65.54	20.24	19.66
T_6	0 ppm Cr + Sl	0.39	0.35	ND	ND
T_7	20 ppm Cr + Sl	15.87	15.26	3.97	3.81
T_8	40 ppm Cr + Sl	31.73	30.57	7.93	7.64
T_9	60 ppm Cr + Sl	47.60	46.04	14.28	13.81
T_{10}	80 ppm Cr + Sl	63.47	62.04	19.04	18.61
T_{11}	0 ppm Cr + FYM	0.35	0.32	ND	ND
T_{12}	20 ppm Cr + FYM	13.97	12.75	3.45	2.98
T_{13}	40 ppm Cr + FYM	28.93	27.82	7.23	6.96
T_{14}	60 ppm Cr + FYM	43.40	42.03	10.85	10.51
T_{15}	80 ppm Cr + FYM	57.87	56.10	14.47	14.03
T_{16}	0 ppm Cr + VC	0.31	0.29	ND	ND
T_{17}	20 ppm Cr + VC	13.07	12.56	3.27	2.86
T_{18}	40 ppm Cr + VC	26.13	25.13	6.53	6.28
T_{19}	60 ppm Cr + VC	39.20	38.06	7.84	8.15
T_{20}	80 ppm Cr + VC	52.27	50.87	10.45	10.82
SEm±		0.71	0.87	0.19	0.24
CD (p=0.01)		2.72	3.32	0.72	0.91

Table 2. Effect of organic amendments and chromium on pH, EC and organic carbon of post-harvest soil. Cr = Chromium, Sl = Sewage sludge, FYM = Farm yard manure, VC = Vermicompost, CD = Critical difference, SEm± = Standard error of mean, EC = Electrical conductivity (desi siemens per meter).

Treatment	pH		EC (dSm^{-1})		Organic carbon (%)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1-Control	7.51	7.59	0.519	0.525	0.505	0.521
T_2-20 ppm Cr	7.40	7.48	0.508	0.514	0.482	0.497
T_3-40 ppm Cr	7.31	7.39	0.494	0.499	0.455	0.469
T_4-60 ppm Cr	7.25	7.33	0.471	0.477	0.369	0.381
T_5-80 ppm Cr	7.16	7.24	0.458	0.463	0.286	0.295
T_6- 0 ppm Cr + Sl	7.60	7.68	0.527	0.533	0.535	0.552
T_7-20 ppm Cr + Sl	7.49	7.57	0.516	0.522	0.511	0.526
T_8-40 ppm Cr + Sl	7.40	7.48	0.502	0.507	0.482	0.497
T_9-60 ppm Cr + Sl	7.34	7.42	0.479	0.484	0.391	0.403
T_{10}-80 ppm Cr + Sl	7.25	7.33	0.465	0.470	0.303	0.312
T_{11}- 0 ppm Cr + FYM	7.68	7.77	0.534	0.539	0.567	0.585
T_{12}-20 ppm Cr + FYM	7.57	7.65	0.523	0.528	0.541	0.558
T_{13}-40 ppm Cr + FYM	7.48	7.56	0.507	0.513	0.511	0.527
T_{14}-60 ppm Cr + FYM	7.42	7.50	0.485	0.490	0.415	0.428
T_{15}-80 ppm Cr + FYM	7.32	7.41	0.471	0.476	0.321	0.331
T_{16}- 0 ppm Cr + VC	7.76	7.84	0.545	0.551	0.601	0.620
T_{17}-20 ppm Cr + VC	7.64	7.73	0.534	0.540	0.574	0.591
T_{18}-40 ppm Cr + VC	7.55	7.63	0.519	0.525	0.542	0.559
T_{19}-60 ppm Cr + VC	7.49	7.57	0.495	0.501	0.440	0.453
T_{20}-80 ppm Cr + VC	7.40	7.48	0.481	0.487	0.340	0.351
SEm±	NS	NS	NS	NS	0.010	0.010
CD (p=0.01)	NS	NS	NS	NS	0.038	0.039

chromium of soil significantly increased as dose of chromium application increased.

DTPA extractable chromium after harvesting of mustard

Data pertaining to DTPA extractable chromium after harvesting of mustard is presented in Table 1. Organic amendments exert significant impact on DTPA extractable chromium after harvesting of mustard in soil contaminated with chromium during both the years. DTPA extractable chromium after harvesting of mustard in soil varied from 3.27 to 20.24 mg/kg and 2.86 to 19.66 mg/kg in the year 2015-16 and 2016-17, respectively. It was found that the application of 20 ppm chromium + vermicompost @ 5 ton/ha (T_{17}) recorded lowest value of DTPA extractable chromium in soil 3.27 and 2.86 mg/kg in 2015-16 and 2016-17, respectively. However, application of 20 ppm chromium + farm yard manure @ 10 ton/ha (T_{12}) was found next better treatment in DTPA extractable chromium in soil 3.45 and 2.98 mg/kg during 2015-16 and 2016-17 which rests at par with treatment T_{17} (20 ppm chromium + vermicompost @ 5 ton/ha). Furthermore, application of 20 ppm chromium + sewage sludge @ 20 ton/ha (T_7) recorded the lower value of DTPA extractable chromium in soil 3.97 and 3.81 in 2015-16 and 2016-17, respectively as compared to 20 ppm chromium which was at par with T_{12} (20 ppm chromium + farm yard manure @ 10 ton/ha) and T_{17} (20 ppm chromium + vermicompost @ 5 ton/ha). Highest value of DTPA extractable chromium in soil 20.24 and 19.66 mg/kg during 2015-16 and 2016-17 was observed in treatment T_5 (80 ppm chromium). From the data we also observed that chromium was not detected in post-harvest soil where chromium was not applied. Data also revealed that DTPA extractable chromium in post-harvest soil increased as level of chromium application increased.

It was also observed that DTPA extractable chromium in soil significantly decreased with organic amendments compared to corresponding chromium treatment. Highest and significant decrement in DTPA extractable chromium in soil was reported with T_{16} (vermicompost @ 5 ton/ha) followed by T_{11} (farm

Table 3. Effect of organic amendments and chromium on N, P, K and S content of post-harvest soil. Cr = Chromium, Sl = Sewage sludge, FYM = Farm yard manure, VC = Vermicompost, CD = Critical difference, SEm± = Standard error of mean.

Treatment	N (mg/kg)		P (mg/kg)		K (mg/kg)		S (mg/kg)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1-Control	84.93	87.05	10.92	11.36	94.34	91.59	17.91	18.63
T_2-20 ppm Cr	82.83	84.90	10.05	10.46	90.85	88.21	15.94	16.58
T_3-40 ppm Cr	79.84	81.84	9.04	9.41	86.40	83.89	13.23	13.76
T_4-60 ppm Cr	76.31	78.21	7.98	8.30	81.73	79.35	10.03	10.44
T_5-80 ppm Cr	72.50	74.31	6.68	6.95	76.25	74.03	6.60	6.86
T_6- 0 ppm Cr + Sl	94.08	96.43	12.81	13.32	113.36	110.07	20.79	21.63
T_7-20 ppm Cr + Sl	91.76	94.05	11.84	12.31	109.17	106.00	18.51	19.25
T_8-40 ppm Cr + Sl	88.45	90.66	10.19	10.60	103.82	100.81	15.61	16.24
T_9-60 ppm Cr + Sl	84.53	86.64	8.74	9.09	98.21	95.35	11.98	12.46
T_{10}-80 ppm Cr + Sl	80.31	82.32	7.33	7.63	91.62	88.95	7.99	8.31
T_{11}- 0 ppm Cr + FYM	98.99	101.46	14.13	14.70	117.63	114.21	22.24	23.13
T_{12}-20 ppm Cr + FYM	96.54	98.96	12.65	13.16	113.29	109.99	19.80	20.60
T_{13}-40 ppm Cr + FYM	93.06	95.39	11.06	11.51	107.74	104.60	16.38	17.03
T_{14}-60 ppm Cr + FYM	88.93	91.16	10.42	10.84	101.91	98.94	12.46	12.96
T_{15}-80 ppm Cr + FYM	84.50	86.61	9.02	9.39	95.07	92.30	8.76	9.11
T_{16}- 0 ppm Cr + VC	103.44	106.03	15.69	16.32	122.97	119.40	23.69	24.64
T_{17}-20 ppm Cr + VC	100.89	103.41	14.61	15.20	118.43	114.98	21.09	21.94
T_{18}-40 ppm Cr + VC	97.25	99.68	13.49	14.03	112.63	109.35	17.42	18.12
T_{19}-60 ppm Cr + VC	92.94	95.26	12.05	12.53	106.53	103.43	13.61	14.15
T_{20}-80 ppm Cr + VC	88.30	90.51	10.68	11.11	99.38	96.49	9.63	10.02
SEm±	1.63	1.68	0.31	0.28	2.74	2.46	0.39	0.33
CD (p=0.01)	6.24	6.41	1.19	1.06	10.49	9.39	1.50	1.28

yard manure @ 10 ton/ha) and T_6 (sewage sludge @ 20 ton/ha). Radziemska *et al.* (2018) reported that the Cr extracted by $CaCl_2$ was significantly lesser than total content in treatments with amendments. Radziemska and Wyszkowski (2017b) observed that compared to control treatment, CaO, compost and zeolite significantly decrease the chromium content in soil.

Magnitude of free ions of metal in solution reduce at soil pH greater than 6 due to enhancement of oxide surface charge, metal hydroxide precipitation and organic matter chelation (Khan *et al.* 2015). Diverse functional groups like phenolic, carboxyl, carbonyl and alcohol isolated from organic materials develops the affinity amongst the functional groups and metal ions at higher pH values (Khan *et al*. 2015).

The rise in OC due to application of organic amendments possibly will be the reason for declining available metal as a consequence of the complex formation among the heavy metals ions and organic amendments (Bashir *et al.* 2017). The extractable Cr concentration with amendments was significantly lesser than the total. This proposes that compared to soil without additives, the soil treated with amendments show better capability to desorb Cr from soil. Immobilization of metals in the experiment with the amendments may be through different means such as: Adsorption of metals to available sites on exterior of amendment and the constituents of soil, and due to liming effects of amendment (Radziemska *et al.* 2018).

Soil pH

The data related to soil pH of post-harvest soil with the application of different organic amendments in Cr contaminated soils provided in Table 2. pH of post-harvest soil exhibited a non-significant difference amongst all the treatments. Soil pH ranged from 7.16 to 7.76 and 7.24 to 7.84 in the year 2015-16 and 2016-17, respectively. We noted that treatment T_{16} (vermicompost @ 5 ton/ha) recorded highest soil pH 7.76 and 7.84 during 2015-16 and 2016-17 and followed by T_{11} (farm yard manure @ 10 ton/ha) with soil pH 7.68 and 7.77 in 2015-16 and 2016-17. Furthermore, application of sewage sludge @ 20 ton/

ha (T_6) recorded the higher soil pH 7.60 and 7.68 in 2015-16 and 2016-17, respectively over control treatment. Whereas, treatment T_5 (80 ppm chromium) observed the minimum soil pH 7.16 and 7.24 in 2015-16 and 2016-17 respectively.

It was also noticed from data that soil pH decreased as chromium level in soil increased. The possible reason of soil pH decrease in current study might be the lack of dissolution of salts in absence of activities of rhizospheric microorganisms by heavy metal and presence of free Fe and Al in soil solution.

Result has also shown that soil pH increased by organic amendments in comparison with the respective chromium treatment. Treatment T_{16} (vermicompost @ 5 ton/ha) was reported maximum increment in soil pH followed by T_{11} (farm yard manure @ 10 ton/ha), followed by T_6 (sewage sludge @ 20 ton/ha). Radziemska *et al.* (2018) showed that addition of amendments increased the soil solutions pH contaminated with Cr. Abbas *et al.* (2017) showed that soil pH increased linearly with the increasing doses of biochar in an agricultural contaminated-soil in comparison with the control. Bashir *et al.* (2017) showed a slight increment in the soil pH on the addition of biochar to metal-contaminated soil compared to control. Jatav *et al.* (2016) pointed out that soil pH did not change significantly with application of sewage sludge but with increasing levels of biochar pH of soil showed a significant increase.

Organic biomass comprises some elementary ingredients, for instance alkali and alkaline earth metals, functional groups on surface comprising oxygen, certain vital plant nutrients (N, P, K, S) and macronutrients (Ca^{2+}, Mg^{2+}) might be transformed to compounds of oxides, hydroxides and carbonates, which could rise the soil pH (Bashir *et al.* 2017).

Electrical conductivity (EC)

The data related to electrical conductivity of post-harvest soil with application of different organic amendments in chromium contaminated soils presented in Table 2. EC of post-harvest soil showed a non-significant difference among the treatments. EC of post-harvest soil varied from 0.458 to 0.545 dS m^{-1} and 0.463 to 0.551 dS m^{-1} in the year 2015-16 and 2016-17, respectively. It is indicated that treatment T_{16} (vermicompost @ 5 ton/ha) recorded highest EC of post-harvest soil 0.545 and 0.551 dS m^{-1} during 2015-16 and 2016-17 and treatment T_{11} (farm yard manure @ 10 ton/ha) was found next higher treatment in EC 0.534 and 0.539 dS m^{-1} in 2015-16 and 2016-17. Furthermore, application of sewage sludge @ 20 ton/ha (T_6) also recorded the higher EC of post-harvest soil 0.527 and 0.533 dS m^{-1} in 2015-16 and 2016-17, respectively as compared to control treatment. Though, the lowest EC of post-harvest soil 0.458 and 0.463 dS m^{-1} in 2015-16 and 2016-17 was observed in T_5 (80 ppm chromium).

Data also presented that EC of post-harvest soil decreased as level of chromium increased. The decrease of EC in post-harvest soil could be because lack of dissolution of salts in absence of activities of soil microorganisms by heavy metal and presence of free Al and Fe in soil solution. Result has also shown that EC of post-harvest soil increased by the organic amendments application in comparison with the respective chromium treatment. Maximum increment in EC was reported with treatment T_{16} (vermicompost @ 5 ton/ha) followed by T_{11} (farm yard manure @ 10 ton/ha), followed by T_6 (sewage sludge @ 20 ton/ha). Abbas *et al.* (2017) showed that the EC increased if levels of biochar increased in contaminated-soil. Saengwilai *et al.* (2017) described that application of amendment was found to improve EC of contaminated soil.

Possible cause for the increase in EC due to organic amendments application might be the high external space and good permeability of organic amendments which raises the cation exchange capacity (CEC) of soil. Therefore, there may possibly be an option for Al and Fe to binding with exchange site of soil. In this study, rise in EC of soil might be attributed to higher EC of amendments and discharge of salts from the amendments.

Soil organic carbon

The data from Table 2 indicated that organic carbon in soil after harvesting of mustard was significantly affected by organic amendments in chromium contaminated soils in both the years. Organic carbon content in post-harvest soil varied from 0.286 to 0.601% and 0.295 to 0.620% in the year 2015-16 and 2016-17, respectively. It is reported that treatment T_{16} (vermicompost @ 5 ton/ha) recorded highest organic carbon content 0.601 and 0.620% in 2015-16 and 2016-17, respectively. Treatment T_{11} (farmyard manure @ 10 ton/ha) was found next to treatment T_{16} in organic carbon content 0.567 and 0.585% in 2015-16 and 2016-17, respectively. Furthermore, application of sewage sludge @ 20 ton/ha (T_6) recorded the significantly higher organic carbon 0.535 and 0.552% in 2015-16 and 2016-17, respectively as compare to control treatment. Application of farmyard manure @ 10 ton/ha was found on par with vermicompost @ 5 ton/ha and sewage sludge @ 20 ton/ha at same level of chromium, however application of vermicompost @ 5 ton/ha was found significantly higher with sewage sludge @ 20 ton/ha with the at all level of chromium except 40 ppm. The lowest organic carbon content 0.286 and 0.295% in 2015-16 and 2016-17 was observed in T_5 (80 ppm chromium).

It was further pointed out that with the increasing level of chromium a significant decreased in organic carbon was observed. Contaminants may upset the microbial activities in soil, thus affect the nutrients transformation cycling and the ability to perform vital ecological functions, such as mineralization of organic compounds and formation of organic matter (Zeng *et al.* 2015).

Result has also shown that organic carbon of post-harvest soil increased significantly with organic amendments in comparison with the respective chromium treatment. Highest significant increment in organic carbon was found with treatment T_{16} (vermicompost @ 5 ton/ha) followed by T_{11} (farm yard manure @ 10 ton/ha), followed by T_6 (sewage sludge @ 20 ton/ha). Bashir *et al.* (2017) recorded highest total organic carbon (TOC) in the control with application of biochar while lowest amount of TOC was recorded with Cd and Cd–Cr-contaminated soil. Saengwilai *et al.* (2017) observed that amendment application was found toward significant improvement in soil organic matter content. The rise in organic carbon due to addition of organic amendments possibly will be the consequence from the presence of high amount of carbon in organic amendments.

Nutrient content of post-harvest soil

Macronutrients (N, P, K and S) content of soil

The data provided in Table 3 showed that macronutrients (N, P, K and S) content of post-harvest soil was significantly influenced by the application of organic amendments in chromium contaminated soils in both the years. Macronutrients (N, P, K and S) content of post-harvest soil varied from 72.50 to 103.44 and 74.31 to 106.03 mg/kg N, 6.68 to 15.69 and 6.95 to 16.32 mg/kg P, 76.25 to 122.97 and 74.03 to 119.40 mg/kg K, 6.60 to 23.69 and 6.86 to 24.64 mg/kg S in the year 2015-16 and 2016-17. It is seen that the treatment T_{16} (vermicompost @ 5 ton/ha) noted maximum macronutrients (N, P, K, S) content in soil 103.44 and 106.03 mg/kg N, 15.69 and 16.32 mg/kg P, 122.97 and 119.40 mg/kg K, 23.69 and 24.64 mg/kg S, during 2015-16 and 2016-17 over rest of the treatments and T_{11} (farm yard manure @ 10 ton/ha) was reported next superior treatment in macronutrient (N, P, K, S) content in soil 98.99 and 101.46 mg/kg N, 14.43 and 14.70 mg/kg P, 117.63 and 114.21 mg/kg K, 22.24 and 23.13 mg/kg S, in 2015-16 and 2016-17, respectively. Likewise, application of sewage sludge @ 20 ton/ha (T_6) recorded the significantly higher macronutrient content of soil 94.08 and 96.43 mg/kg N, 12.81 and 13.32 mg/kg P, 113.36 and 110.07 mg/kg K, 20.79 and 21.63 mg/kg S, in 2015-16 and 2016-17 in comparison to the control. Lowest content of macronutrients (N, P, K, S) in soil 72.50 and 74.31 mg/kg N, 6.68 and 6.95 mg/kg P, 76.25 and 74.03 mg/kg K, 6.60 and 6.86 mg/kg S, in 2015-16 and 2016-17 respectively were observed in treatment T_5 (80 ppm chromium). Further investigation of data revealed that macronutrients (N, P, K, S) content in soil decreased significantly as level of chromium increased.

In our study, the decrease in macronutrient content of soil with chromium contamination might be resulted from inhibition of soil microbiological processes. Contaminants may upset the microbial activities in soil, thus affect the nutrients transformation cycling and the ability to perform vital ecological functions, such as mineralization of organic compounds and formation of organic matter (Zeng

Table 4. Effect of organic amendments and chromium on Fe, Cu, Mn and Zn content of post-harvest soil. Cr = Chromium, Sl = Sewage sludge, FYM = Farm yard manure, VC = Vermicompost, CD = Critical difference, SEm± = Standard error of mean.

Treatment	Fe (mg/kg)		Cu (mg/kg)		Mn (mg/kg)		Zn (mg/kg)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1-Control	29.45	30.94	2.02	2.16	8.96	9.58	0.77	0.83
T_2-20 ppm Cr	23.56	24.75	1.75	1.88	7.62	8.16	0.66	0.70
T_3-40 ppm Cr	16.49	17.32	1.35	1.45	5.71	6.12	0.49	0.53
T_4-60 ppm Cr	9.90	10.39	0.90	0.97	3.71	3.88	0.32	0.34
T_5-80 ppm Cr	4.95	5.20	0.52	0.55	2.04	2.19	0.18	0.19
T_6- 0 ppm Cr + Sl	35.86	37.66	3.03	3.24	12.65	13.54	1.55	1.66
T_7-20 ppm Cr + Sl	29.05	30.51	2.67	2.85	10.88	11.64	1.33	1.43
T_8-40 ppm Cr + Sl	20.63	21.66	2.08	2.23	8.27	8.85	1.01	1.08
T_9-60 ppm Cr + Sl	12.58	13.21	1.41	1.51	5.46	5.84	0.67	0.72
T_{10}-80 ppm Cr + Sl	6.42	6.74	0.82	0.88	3.06	3.27	0.37	0.40
T_{11}- 0 ppm Cr + FYM	43.04	45.17	4.13	4.42	16.41	17.55	2.27	2.43
T_{12}-20 ppm Cr + FYM	35.08	36.82	3.66	3.91	14.19	15.18	1.96	2.10
T_{13}-40 ppm Cr + FYM	25.08	26.32	2.87	3.07	10.86	11.61	1.50	1.61
T_{14}-60 ppm Cr + FYM	15.43	16.19	1.97	2.10	7.22	7.72	1.00	1.07
T_{15}-80 ppm Cr + FYM	7.94	8.34	1.15	1.23	4.08	4.36	0.56	0.60
T_{16}- 0 ppm Cr + VC	48.74	51.17	5.20	5.56	20.29	21.71	3.02	3.23
T_{17}-20 ppm Cr + VC	39.97	41.96	4.62	4.94	17.65	18.88	2.63	2.81
T_{18}-40 ppm Cr + VC	28.78	30.21	3.65	3.91	13.59	14.54	2.02	2.16
T_{19}-60 ppm Cr + VC	17.84	18.73	2.52	2.70	9.11	9.74	1.36	1.45
T_{20}-80 ppm Cr + VC	9.28	9.74	1.49	1.59	5.19	5.55	0.77	0.81
SEm±	0.65	0.67	0.06	0.05	0.24	0.22	0.03	0.03
CD (p=0.01)	2.47	2.55	0.24	0.21	0.93	0.84	0.13	0.11

et al. 2015).

It is also observed that organic amendments significantly increased macronutrients (N, P, K, S) content in soil, compared to the respective chromium treatment. Highest significant increment in macronutrients (N, P, K, S) content of soil was recorded with T_{16} (vermicompost @ 5 ton/ha) followed by T_{11} (farm yard manure @ 10 ton/ha), followed by T_6 (sewage sludge @ 20 ton/ha). Saengwilai *et al.* (2017) reported that amendment improve soil physico-chemical properties, in particular, nutrient such as N, P, K, Ca, Mg increased significantly. Kohler *et al.* (2015) revealed that organic amendment almost doubling the available P and whole N in rhizosphere of non-inoculated and Glomus inoculated plants in metal polluted mine tailing with respect to control soil, and also stimulated soil microbial activities. Rise in nutrient content with organic amendments principally attributed to occurrence of these nutrients in the organic amendments themself.

Micronutrients (Fe, Zn, Cu, Mn) content of soil

Data associated to micronutrients (Fe, Zn, Cu, Mn) content in soil after harvesting of mustard is given in Table 4. From the Table it is revealed that micronutrients (Fe, Zn, Cu, Mn) content in soil after harvesting of mustard was affected significantly with application of organic amendments in chromium contaminated soils during both the years. Micronutrients (Fe, Zn, Cu, Mn) content in post-harvest soil ranges from 4.95 to 48.74 and 5.20 to 51.17 mg/kg Fe, 0.18 to 3.02 and 0.19 to 3.23 mg/kg Zn, 0.52 to 5.20 and 0.55 to 5.56 mg/kg Cu, 2.04 to 20.29 and 2.19 to 21.71 mg/kg Mn during 2015-16 and 2016-17. Treatment T_{16} (vermicompost @ 5 ton/ha) recorded highest micronutrients (Fe, Zn, Cu, Mn) content 48.74 and 51.17 mg/kg Fe, 3.02 and 3.23 mg/kg Zn, 5.20 and 5.56 mg/kg Cu, 20.29 and 21.71 mg/kg Mn of soil in 2015-16 and 2016-17, respectively and T_{11} (Farm yard manure @ 10 ton/ha) was noted subsequent superior treatment in micronutrients (Fe, Cu, Mn, Zn) content 43.04 and 45.17 mg/kg Fe, 2.27 and 2.43 mg/kg Zn, 4.13 and 4.42 mg/kg Cu, 16.41 and 17.55 mg/kg Mn of post-harvest soil in 2015-16 and 2016-17. Besides, application of sewage sludge @ 20 ton/ha (T_6) recorded the significantly higher micronutrients (Fe, Zn, Cu, Mn) content 35.86 and 37.66 mg/kg Fe, 1.55 and 1.66

mg/kg Zn, 3.03 and 3.24 mg/kg Cu, 12.65 and 13.54 mg/kg Mn in post-harvest soil during 2015-16 and 2016-17, respectively compared to control. Whereas, minimum micronutrients (Fe, Zn, Cu, Mn) content of soil 4.95 and 5.20 mg/kg Fe, 0.18 and 0.19 mg/kg Zn, 0.52 and 0.55 mg/kg Cu, 2.04 and 2.19 mg/kg Mn in 2015-16 and 2016-17 respectively were observed in treatment T_5 (80 ppm chromium). Data related to micronutrients content also revealed that micronutrients content of soil decreased significantly with increasing level of chromium in soil.

In present study, the decrease in micronutrients (Fe, Zn, Cu, Mn) content in soil with chromium contamination might be consequence of inhibition of soil microbiological process. Contaminants may upset the microbial activities in soil, thus affect the nutrients transformation cycling and the ability to perform vital ecological functions, such as mineralization of organic compounds and formation of organic matter (Zeng *et al.* 2015).

Result has also shown that organic amendments significantly increased the micronutrients (Fe, Zn, Cu, Mn) content of soil in comparison to the respective treatment of chromium. Maximum increment in micronutrients (Fe, Zn, Cu, Mn) content of soil was found with treatment T_{16} (vermicompost @ 5 ton/ha) followed by T_{11} (farm yard manure @ 10 ton/ha), followed by T_6 (sewage sludge @ 20 ton/ha). Radziemska and Wyszkowski (2017b) found that compared with control groups, copper, zinc, cobalt content in soil of pots with Cr (VI) increased significantly by the addition of compost.

Rise in trace elements may be because of the better microbial activities in soil (Ahmad *et al.* 2016) and/or due to deliverance of nutrients from amendments (Rehman *et al.* 2016). Application of composts has beneficial influence on the physico-chemical features of soil, including contamination of soil with chromium (Radziemska and Wyszkowski 2017a). The increase in the bioavailability of micronutrients in our study might be due to variants of metal concentrations in organic materials used for amendments (Abbas *et al.* 2017).

CONCLUSION

Results of our experiment elaborate that organic amendments are excellent alternative for dealing with the antagonistic effect of chromium in soil. Chemical properties (pH, EC, organic carbon, DTPA extractable Cr and nutrients content) of soil adversely affected by chromium and it was also observed that soil chemical properties are negatively correlated with the level of chromium. Organic amendments are worthwhile in alleviating the negative effect of chromium toxicity. Vermicompost found most important in all the amendment. There is considerable difference in efficacy of individual amendment to reduce the chromium toxicity. Hence, we can say that each and every amendment does not have similar ability to reduce the antagonistic effect of chromium. Therefore, it can be advocated that alleviation of toxicity is depending on type of a particular amendment.

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