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Importance of FYM and vermicompost on NPK content and uptake by rice (*Oryza sativa*) in chromium contaminated soil

K Ramya Krishna, PK Sharma, Vipin Kumar, Jiten Behera, Sravani Katkuri and Shikha

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K Ramya Krishna
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

PK Sharma
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Vipin Kumar
Doon School of Agriculture and Allied Sciences, Doon Business School, Selaqui, Dehradun, Uttarakhand, India

Jiten Behera
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Sravani Katkuri
Department of Agronomy Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Shikha
Krishi Vigyan Kendra, VCSG UUHF, Ranichauri, Tehri Garhwal, Uttarakhand, India

Abstract

Chromium is a serious heavy metal and it is considered as an environmental hazard. The contamination of the soil environment with chromium compounds is more and more frequently occurring problem throughout the world. Chromium (Cr) contamination in soil is a growing concern in sustainable agriculture production and food safety. Keeping these points in view pot experiment was conducted in net house of Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during 2016-17 to study the effect of FYM and vermicompost on nutrients content and uptake by Rice (*oryza sativa*) in chromium contaminated soil. Five levels of chromium viz. 0, 20, 40, 60 and 80 ppm with and without vermicompost @ 5 ton ha^{-1} and farm yard manure @ 10 ton ha^{-1} were taken. The NPK content of rice straw and grain decreased with increase in the levels of chromium i.e., maximum decrease was observed in treatment Cr80. However, the treatment of Cr20 and Cr 40 were found statistically at par with treatment Cr0. Increasing chromium levels resulted in significant increase in NPK content of the rice straw up to the treatment Cr20 tested in the experiment and then reduced with an increase in chromium concentration. NPK content in grain and straw was found significantly higher under use of organic sources. The highest NPK content found in vermicompost treated pots followed by FYM treated pots. Our results confirm that the rice can play an effective role in bioremediation of soils polluted with chromium, particularly in supplementation with organic amendments such as farm yard manure and VC.

Keywords: Rice, chromium, FYM, vermicompost, NPK content and uptake

Introduction

Chromium (Cr) is the 7th most abundant element in the Earth and the 21st on the Earth's crust (Ertani *et al.*, 2017) [8]. The contamination of the soil environment with chromium compounds is more and more frequently occurring problem throughout the world (Radziemska and Wyszkowski, 2017) [25]. Chromium pollution of soil and water is a serious environmental concern due to potential carcinogenicity of hexavalent chromium [Cr(VI)] when ingested (Choudhary *et al.*, 2017) [7]. Cr is widely used in industry as plating, alloying, tanning of animal hides, inhibition of water corrosion, textile dyes and mordants, pigments, ceramic glazes, refractory bricks, and pressure-treated lumber (Lukina *et al.*, 2016) [18]. With the development of industrial activities including chromate production, electroplating and leather tanning, hexavalent chromium (Cr(VI)) has been widely detected in soil (Su *et al.*, 2016; Lukina *et al.*, 2016) [18, 30]. Chromium, due to its structural similarity with some essential elements, can affect mineral nutrition of plants in a complex way. Interactions of Cr with uptake and accumulation of other inorganic nutrients have received maximum attention by researchers (Kumar *et al.*, 2016) [15].

Remediation of heavy metals polluted soil could be carried out using physicochemicals processes such as ion exchange, precipitation, reverse osmosis, evaporation and chemical reduction. However, the measures require external man-made resources and therefore are very costly (Mangkoedihardjo and Surahmaida, 2008) [19]. Plant-based bioremediation technologies have received recent attention in order to clean-up contaminated soil and water. These strategies have collectively termed as phytoremediation which refers to the use of green plants and their associated micro biota for the in-situ treatment of contaminated soil, sediment and as well as ground water. Biological based remediation strategies, which include phytoremediation, have been estimated to be four to 1000 times cheaper, on volume basis, than current non-biological technologies. For a country like India, phytoremediation is best suited as it requires low investment, and relies on plants natural capability to take up metal ions from soil (Ghosh and Singh, 2005) [9].

Correspondence
Vipin Kumar
Doon School of Agriculture and Allied Sciences, Doon Business School, Selaqui, Dehradun, Uttarakhand, India

The organic manure is eco-friendly and economically viable, which also plays a significant role in soil biology, chemistry, and physics. The use of organic amendments on heavy metal remediation has been influenced by the composition of salt content, and manure, effects on soil pH, and their effect on microbes, redox potential, and the specific soil and metals concerned (Walker *et al*., 2004) [32]. These organic sources may be organic manures, green manure, rural wastes, crop residues, biofertilizers and vermicompost (Kumar *et al*., 2018a) [12]. Organic and inorganic amendments are used for immobilization of metals in the soils with varying benefits but organic amendments could be better option due to improvement of physical, chemical, biological properties and fertility status of the soil (Park *et al*., 2011) [24]. The mobility and toxicity of Cr^{6+} can be reduced by converting it to the reduced state of Cr^{3+} by means of organic matter and inorganic reducing agents in the soil (Aceves *et al*., 2007; Kumar and Sharma, 2018) [1, 14]. The immobilizing effect of organic amendments are thought to act through various complex processes *e.g.* formation of stable compounds with organic ligands, surface precipitation and ion exchange (Kumpiene *et al*., 2008; Ahmad *et al*., 2011a) [16, 2]. Immobilization of metals in contaminated soils using amendments is a remediation technique that decreases mobility and phytoavailability of metals in the soils (Sabir *et al*., 2013; Rizwan *et al*., 2016; Rehman *et al*., 2017) [28, 27, 26].

FYM positively controls the crop production and recovers properties of soil and it can be used to decrease heavy metal stress in plants. Farm yard manure (FYM) positively influence crop production, improved soil physical, chemical, and biological properties (Ould Ahmed *et al*., 2010; Alam *et al*., 2014) [23, 3] and can be used to reduce heavy metal hazards in plants (Yassen *et al*., 2007) [34]. Farm yard manure application to the soil could be used as an effective measure for reducing Cr toxicity to crop plants in Cr-contaminated soils (Singh *et al*., 2007) [29].

Vermicompost is a natural organic product which is eco-friendly; it does not leave any adverse effects either in the soil or in the environment (Kumar *et al*., 2018b) [13]. The vermicompost contain high nutrient value, increases fertility of soil and maintains soil health (Suthar *et al*., 2005) [31]. Application of vermicompost in contaminated soil improves soil fertility and physical properties as well as helps in successful approach to phytoremediation (Zheljazkov and Warman, 2004; Jadia and Fulekar, 2008) [35, 11].

However, information is hardly available on the phytotoxicity of Cr in cereals and its remedy. So, the pot experiment was taken for the study of toxic effects of Cr with amendments *viz*., FYM and Vermicompost to reduce the adverse effects of Cr on nutrients content and uptake by Rice (*oryza sativa*) in chromium contaminated soil.

Material and Methods

Nutrient content

At harvest, the plant and grain samples were collected from each pot for chemical estimation and the samples were dried in an oven at 70ºC for 48 hours, the plant material thus obtained was ground with the help of grinder and passed through 20 mesh sieve and preserved separately for determination of N, P and K content. The nutrient content was then estimated as per following methods.

Wet Digestion of plant samples

0.5 gram dried and powdered plant sample (20 mesh) was taken in a 50 mL digestion tube and 10 mL di-acid mixture (9:4 v/v HNO_3: $HClO_4$) was added to it and was kept overnight. It was then digested on a block digester till a colourless solution was obtained. The volume of acid was reduced till the flask contained only moist residue. The flask was cooled and 25 mL of distilled water was added. The solution was filtered into a 50 mL volumetric flask and diluted up to mark.

Digestion of plant samples for Nitrogen determination

0.5 gram dried and powdered plant sample (20 mesh) was taken in a 50 mL digestion tube and digested with 10 mL sulfuric acid on a block digester till a colourless solution was obtained. The volume of acid was reduced till the tube contained only moist residue. The tube was cooled and 25 mL of distilled water was added. The solution was filtered into a 50 mL volumetric flask and diluted up to mark.

Estimation of Nitrogen

Nitrogen was determined by the Kjeldahl method as described by Jackson (1973) [10]. In a conical flask 20 ml of 4% boric acid solution containing bromocresol green and methyl red mixed indicator was transferred, to which outlet hosepipe was dipped. 10 ml of digest was taken into distillation tube of Kjeltec Semi-Auto Nitrogen Analyzer (Pelican) and 40 ml of 40% NaOH was added. Five ml of aliquot was distilled to conical flask containing boric acid. After completion of distillation, the boric acid was titrated with 0.02 N sulfuric acid solution till original brick red colour end point of boric acid.

Calculation

$$\text{Percent N in Plant material} = \frac{0.02 \times \text{T} \times 0.014 \times 50 \times 50}{10 \text{ x } 5}$$

Where, T = Sample reading - Blank reading

Estimation of Phosphorous

Phosphorous was determined by Vanadomolybdate yellow colour method given by Jackson (1973) [10]. Vanadate, molybdate and orthophosphates react together to give a yellow colour complex in nitric acid medium. 10 ml of digested aliquot was transferred into 50 ml volumetric flask, 10 ml of vanadomolybdate reagent was added, made up to mark with double distilled water and shaken well to mix properly. After 30 min absorbance was taken at 420 nm on spectrophotometer.

Calculation

$$\text{Percent P in Plant material} = \frac{\text{C} \times 100 \times \text{Volume of digest}}{\text{Wt. Of sample (g)} \times \text{aliquot taken ml} \times 10000}$$

Where, C = concentration of P in aliquot (obtained from std. curve)

Estimation of Potassium

Potassium was determined by the Flame photometer following Jackson (1973) [10] method. Reading was taken on flame photometer in digested aliquot.

Calculation

$$\text{Percent K in Plant material} = \frac{\text{R} \times \text{dilution factor}}{10000}$$

Where, R = Flame photometer reading

Nutrient uptake

Nutrient uptake was also calculated by following formulae

Nutrient uptake in straw and grain was calculated in g/pot in relation to dry-matter production per pot by using the following formula:

$$\text{Nutrient uptake (g /pot)} = \frac{\text{Nutrient content (\%)} \times \text{Yield (g/ pot)}}{100}$$

Results and Discussion

Effect of chromium levels and organic amendments on nutrient content and uptake of rice straw and grain

Data pertaining to analyses of N, P and K contents in grain and straw and their uptake as effected by chromium levels and organics sources have been presented in Table 1, 2, 3 respectively.

Nitrogen content in straw and grain (%)

The nitrogen content in grain and straw has been depicted in Table 1. Data revealed that nitrogen content found highest in grain (1.02) compared to straw (0.42). Grain nitrogen content decreased with increase in the levels of chromium. The maximum reduction was seen at treatment Cr80.However, the treatment of Cr0 found statistically at par with treatment Cr20 and Cr 40 and all these treatments proved significantly higher Nitrogen content than treatment Cr 80. Increasing chromium levels resulted in significant increase in nitrogen content of the rice straw up to the treatment Cr 20 tested in the experiment. There was the highest reduction in nitrogen content compared to P and K when interacted with chromium.

The nitrogen content in grain and straw of rice was found significantly higher under use of organic sources i.e. FYM and vermicompost over control plant which contained minimum nitrogen content. However, application of vermicompost and FYM differ significantly among them regarding nitrogen content in grain and straw. The interaction effect between chromium and organic sources regarding nitrogen content in grain and straw failed to reach the level of significance.

Uptake of nitrogen by straw and grain (g pot^{-1})

Data pertaining to the uptake of nitrogen by grain and straw has been presented in Table 1. Perusal of the data indicates that control pots registered significantly higher uptake of nitrogen by grain (0.29 g pot^{-1}) followed by straw (0.23 g pot^{-1}). However, treatment Cr20 and Cr40 ppm remained statistically at par with control Cr0 in the case of nitrogen uptake by grain. Similar results found in case with nitrogen uptake by straw of rice. The uptake of nitrogen decreased progressively with increasing levels of chromium up to 80ppm and showed a significant decrease with increase in the levels of chromium.

Further, it is evident from the data that the Vermicompost and FYM increased uptake of N by grain as well as straw. Minimum nitrogen uptake by straw was observed in treatment Cr80.Addition of FYM and vermicompost increased nitrogen uptake significantly in all the treatments. The interaction effect between chromium levels and organic sources regarding nitrogen uptake by grain and straw could not reach up to the level of significance. The reduction in nitrogen compounds could be due to reduced root growth and impaired penetration of the roots in the soil due to Cr toxicity similar results reported by Azmat and Khanum (2005) [4].

Phosphorus content in straw and grain (%)

Phosphorus content in grain and straw as affected by chromium concentrations and organic sources have been compiled in Table 2. Data revealed that minimum phosphorus content in grain and straw was found under treatment Cr80. However, the treatments Cr0, Cr20, and Cr40 differ significantly among themselves in respect of phosphorus content of grain and straw. Phosphorus content found highest in grain compared to straw. The reduction in the nutrient content may be due to the inhibition of enzymes involved in the synthetic process (Balashouri and Devi, 1994) [5].

As regards the organic sources, the treatment Cr0+VC recorded highest phosphorus content in grain and straw though proved significantly higher over the treatment Cr0 alone. However, treatment Cr0+VC found statistically at par with Cr0+FYM regarding phosphorus content in grain and straw. The interaction effect between chromium levels and organic sources in respect to nitrogen content in grain and straw was recorded non-significant. The addition of organic materials increased the intractable fraction of phosphorus and Microbial activity and thus biochemical transformation reported by Nziguheba (1998) [22].

Uptake of phosphorus by straw and grain (g pot^{-1})

Summary of data on phosphorus uptake as affected by treatments was presented in Table 2. However, treatment Cr0 remained statistically at par with treatment Cr20 in the case of phosphorus uptake by grain. Similar results were found in case with phosphorus uptake by straw of rice. The uptake of nitrogen decreased progressively with increasing levels of chromium up to 80ppm and showed a significant decrease with increase in the levels of chromium.

In response with organic sources, the treatment Cr0+VC recorded highest phosphorus content in grain (0.44 %) and straw (0.27%) followed by Cr0 +FYM i.e., grain(0.35%) and straw (0.24%) though it was significantly higher over the treatment Cr0. However, treatment Cr0+ VC found statistically at par with Cr0+FYM regarding phosphorus content in grain and straw. The uptake of phosphorus by grain as well as straw was recorded significantly higher under Cr0+VC followed by Cr0+FYM when compared to Cr0. The connections with the soil mechanism to increased phosphorus uptake by the plants are most important (Whalen, 2001) [33].

Potassium content in straw and grain (%)

Potassium content in grain and straw as affected by chromium concentrations and organic sources had been compiled in Table 3. Data revealed that minimum potassium content in grain and straw was found under treatment Cr80 which exhibited significantly lowest potassium content over rest of treatments. However, the treatments Cr0, Cr20, and Cr40 differ significantly among themselves in respect of potassium content of grain and straw.

As regards the organic sources, the treatment Cr0+VC recorded the highest potassium, content in grain and straw though proved significantly higher over the treatment Cr0 alone. Potassium content found highest in straw compared to grain. However, treatment Cr0+ VC found statistically at par with Cr0+FYM regarding potassium content in grain and straw. The interaction effect between chromium levels and organic sources in respect to potassium content in grain and straw was recorded non-significant.

Uptake of potassium by straw and grain (g pot^{-1})

The data pattern on the uptake of potassium by grain and straw are presented in Table 3. Highest uptake was found in straw compared to grain. Data indicated that maximum uptake of potassium by grain and straw was recorded in treatment Cr0. Minimum uptake of potassium by grain and straw was recorded under 80 ppm chromium concentration in control condition. It may be due to the competition of chromium ions with potassium, which in turn exercised a regulatory control on potassium uptake (Lamoreaux and Chaney, 1978) [17].

Removal of potassium by grain and straw was significantly higher under combined application of vermicompost though it was observed at par with treatment FYM observed significantly higher than use of NPK alone in respect of grain. However, potassium removal by straw increased significantly with the addition of organics. With the addition of organics higher uptake of N, P and K occurs because of better root penetration leading to better absorption due to greater availability and improved soil physical condition, similar results reported by Meena *et al.* (2010) [20].

Table 1: Effect of FYM and vermicompost on N content (%) and uptake (g pot^{-1}) of rice straw and grain in chromium contaminated soil

Treatments	N content (%)		N uptake (g pot^{-1})		Total N uptake (g pot^{-1})
	straw	grain	straw	grain	
Cr 0	0.42	1.08	0.23	0.28	0.51
Cr20	0.44	1.15	0.23	0.29	0.52
Cr 40	0.34	1.07	0.18	0.26	0.44
Cr 60	0.28	0.97	0.14	0.22	0.36
Cr 80	0.24	0.57	0.08	0.12	0.2
Cr0+FYM	0.56	1.47	0.35	0.43	0.78
Cr 20+FYM	0.54	1.43	0.34	0.40	0.74
Cr 40+FYM	0.48	1.41	0.29	0.37	0.66
Cr60+FYM	0.44	1.35	0.25	0.34	0.59
Cr 80+FYM	0.36	1.1	0.21	0.27	0.48
Cr0+VC	0.63	1.85	0.52	0.58	1.1
Cr20+VC	0.56	1.87	0.47	0.57	1.04
Cr40+VC	0.52	1.74	0.40	0.49	0.89
Cr60+VC	0.46	1.67	0.33	0.44	0.77
Cr80+VC	0.4	1.6	0.29	0.41	0.7
SEm ±	0.02	0.08	0.02	0.02	0.04
CD (P=0.01)	0.05	0.22	0.05	0.06	0.11

Table 2: Effect of FYM and vermicompost on P content (%) and uptake (g pot^{-1}) of rice straw and grain in chromium contaminated soil

Treatments	P content (%)		P uptake(g pot^{-1})		Total P uptake (g pot^{-1})
	straw	Grain	straw	grain	
Cr 0	0.18	0.25	0.067	0.07	0.14
Cr20	0.16	0.23	0.058	0.06	0.12
Cr 40	0.14	0.2	0.046	0.05	0.10
Cr 60	0.12	0.19	0.037	0.04	0.08
Cr 80	0.09	0.17	0.027	0.03	0.06
Cr0+FYM	0.24	0.35	0.101	0.10	0.20
Cr 20+FYM	0.22	0.32	0.090	0.09	0.18
Cr 40+FYM	0.2	0.27	0.076	0.07	0.15
Cr60+FYM	0.16	0.25	0.060	0.06	0.12
Cr 80+FYM	0.13	0.22	0.048	0.05	0.10
Cr0+VC	0.27	0.44	0.144	0.14	0.28
Cr20+VC	0.24	0.42	0.129	0.13	0.26
Cr40+VC	0.21	0.39	0.110	0.11	0.22
Cr60+VC	0.18	0.37	0.090	0.10	0.19
Cr80+VC	0.16	0.35	0.076	0.09	0.17
SEm ±	0.01	0.02	0.005	0.01	0.02
CD	0.02	0.06	0.014	0.02	0.03

Table 3: Effect of FYM and vermicompost on K content (%) and uptake (g pot^{-1}) of rice straw and grain in chromium contaminated soil

Treatments	K content (%)		K uptake(g pot^{-1})		Total K uptake (g pot^{-1})
	straw	grain	straw	grain	
Cr 0	1.24	0.39	0.26	0.10	0.36
Cr20	1.21	0.37	0.27	0.09	0.36
Cr 40	1.13	0.34	0.28	0.08	0.36
Cr 60	1.07	0.32	0.29	0.07	0.36
Cr 80	0.94	0.3	0.29	0.06	0.35
Cr0+FYM	1.48	0.43	0.35	0.13	0.48
Cr 20+FYM	1.33	0.39	0.36	0.11	0.47
Cr 40+FYM	1.3	0.38	0.37	0.10	0.47
Cr60+FYM	1.28	0.33	0.34	0.08	0.42
Cr 80+FYM	1.24	0.32	0.33	0.08	0.41
Cr0+VC	2.00	0.46	0.45	0.14	0.6

Cr20+VC	1.89	0.43	0.47	0.13	0.6
Cr40+VC	1.68	0.42	0.48	0.12	0.6
Cr60+VC	1.57	0.41	0.44	0.11	0.55
Cr80+VC	1.37	0.37	0.42	0.09	0.51
SEm ±	0.08	0.04	0.01	0.01	0.02
CD	0.23	0.12	0.03	0.02	0.05

Conclusion

The experiment depicted that NPK content of rice straw and grain decreased with increase in the levels of chromium i.e., maximum decrease was observed in treatment Cr80. However, the treatment of Cr20 and Cr40 were found statistically at par with treatment Cr0. Increasing chromium levels resulted in significant increase in NPK content of the rice straw up to the treatment Cr20 tested in the experiment and then reduced with an increase in chromium concentration. NPK content in grain and straw was found significantly higher under use of organic sources. The addition of these organic amendments has significantly increased NPK content. The highest NPK content found in vermicompost treated pots followed by FYM treated pots.

NPK uptake in rice straw and grain showed a significant decrease with increase in the levels of chromium. However, treatment Cr20 and Cr40 ppm remained statistically at par with control Cr0 in the case of NPK uptake by grain. Similar results found in the case with nitrogen, phosphorus, potassium uptake by straw of rice. The treatment i.e., Vermicompost and FYM, the treatment Cr0+VC has up taken higher N, P, K by grain as well as straw. N, P, K uptake by straw and grain was observed minimum with treatment Cr80 and with the addition of FYM and vermicompost increased NPK uptake significantly. The nitrogen phosphorus uptaken more in grain whereas potassium uptake more in the case of straw.

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