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Efficiency of Rice Straw and Its Different Composts in Remediation of Cd and Pb Contaminated Sandy Loam Soil

Maha Mohamed El-Sayed Ali[1*]

[1]*Soil Science Department, Faculty of Agriculture, Benha University, Moshtohor, Toukh, Kalyoubia, 13736, Egypt.*

Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Remediation of heavy metals contaminated soils is necessary to reduce heavy metals availabilities and their uptake by crops. Development of cost-effective amendments is still a very important task in the soil environmental system for decreasing hazardous of heavy metals, and improving soil quality and crop production in low fertile and polluted soils. A pot experiment was carried out to determine the efficiency of rice straw (RS), rice straw compost (RSC) and rice straw-farmyard manure compost (RSFC) at three rates (0.25, 0.50 and 1%) in the amelioration of Cd and Pb polluted loamy sand soil. Faba bean plant was selected to be as an indicator plant in this experiment. The addition of RS, RSC and RSFC caused significant increases in soil chemical properties such as soil pH, organic matter (OM) and available phosphorus (AP). Application of RS, RSC and RSFC led to high reductions in soil available Pb and Cd contents. Availabilities of Pb and Cd were highly affected by soil chemical properties. Incorporation of RS, RSC and RSFC improved the growth of bean plants and decreased accumulations of Cd and Pb in their straw, roots and seeds. Absorptions of Cd and Pb were significantly decreased with increasing rates of RS, RSC and RSFC. The greatest seed yields of bean (5.12 and 6.00 g pot^{-1}) were noticed at 1% RSC and 1% RSFC, respectively. Our study suggests that RS, RSC and RSFC are suitable organic amendments to improve fertility and quality of the chosen heavy metals contaminated sandy loam soil.

**Corresponding author: E-mail: maha.ali@fagr.bu.edu.eg, maha_fagr.bu1984@yahoo.com;*

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1. INTRODUCTION

Contamination of agricultural soils with heavy metals has received a widespread consideration in the recent years. Cadmium (Cd) and lead (Pb) are hazardous heavy metals and gain a great concern in the environmental studies owing to their high toxicities on plants, animals and humans [1,2]. Both of Cd and Pb can accumulate in plants with high levels causing high inhibition for their growth and nutrient absorption, and harmful health problems for human through eating these plants [3,4]. Accumulations of Cd and Pb in soils can be resulted from mining and smelting activities, and application of sewage sludge, industrial wastes and low grade fertilizers [1,5]. Lead (Pb) has very low mobility in the soil because of its high retention with soil particles, so it can stay long times in the soil around 150-5000 years [6]. Many studies indicated that Cd and Pb are non-essential nutrients for plants, animals and humans, and also they are un-degradable elements [7]. Hence, numerous methods are developed for treating heavy metals contaminated soils.

Amelioration of heavy metals contaminated soils can be done generally through biological, chemical and phyto-remediation techniques [8]. Some remediation technologies such as thermal and electro treatments, and landfill are unsuitable for rehabilitation of polluted soils due to their high cost and low effectiveness [9,10]. Phytoremediation is a low-cost and safe remediation method, and receives huge awareness in recent years to remove heavy metals from the soil but it is still facing some applied problems due to the low biomass of hyper accumulator plants and low removal rates of heavy metals [11]. Accordingly, chemical remediation becomes as an alternative technique and one of the most superlative ways to ameliorate metals polluted soils due to its cost-effectiveness and fast performance [12]. Chemical immobilization of heavy metals can be applied using some mineral and organic amendments [8,12-14]. Organic amendments have high nutritional values for supporting plant growth and containing essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), and also trace elements such as copper (Cu) and zinc (Zn) [15]. Organic amendments such as rice straw, chicken manure compost, green manure and pig manure showed high efficiency in the remediation of heavy metals contaminated soils through altering heavy metals from soluble fractions to non-available forms bounded with organic matter or precipitated with carbonate and phosphate ions [8,12-14]. Although many pot and field experiments have been conducted to evaluate the effect of organic amendments on the immobilization of heavy metals, limited studies have been focused on using rice straw composts as an *in situ* remediation method to ameliorate heavy metal contaminated soils.

Faba bean (*Vicia faba* L.) is one of the most important legume crops and mainly grown in the winter season in many places around the world such as East Asia, North Africa, Southern Europe and the Nile Valley region under rained or irrigated conditions [16]. Diminishing Cd and Pb absorptions by bean plants is an important task to avoid their harmful problems on human health. Therefore, this study aimed to investigate the effect of rice straw (RS), rice straw compost (RSC) and rice straw-farmyard manure compost (RSFC) at different levels on soil chemical properties, growth of bean and absorptions of Cd and Pb by bean tissues.

2. MATERIALS AND METHODS

2.1 Soil Samples

Sub-surface soil samples (0-30 cm depth) were collected from Al-Gabal Al-Asfar zone (30º12'0" N and 31º22'0" E), Qalyubia Governorate, Egypt. The soil was contaminated with heavy metals due to the use of sewage sludge as an organic fertilizer and waste water (sewage effluent) as an irrigation source. The physical and chemical properties of the collected soil are presented in Table 1.

2.2 Faba Bean Seeds and Fertilizers

Seeds of faba bean were obtained from Agronomy Department, while nitrogen-fixing bacteria (*Rhizobium leguminosarum*) and effective microbes solution (EM) were collected from Microbiology Department at the Agricultural Research Center (ARC), Dokki, Giza Governorate, Egypt. Fertilizers (urea, super phosphate and potassium sulfate fertilizers) and microelement fertilizers (Fe, Mn, Zn and Cu) were collected from the Agricultural Research Center and Soil Science Department, respectively at Faculty of Agriculture, Benha University, Qalyubiyah Governorate, Egypt.

Table 1. Physical and chemical properties of the studied soil

Soil properties	Values
pH *	6.91(0.33)
EC * dS m^{-1}	1.14 (0.04)
OM g kg^{-1}	21.3 (2.61)
Sand %	78.6 (8.35)
Silt %	9.83 (0.76)
Clay %	11.57 (0.87)
Texture	Sandy loam
Total N g kg^{-1}	4.23 (0.17)
Total P g kg^{-1}	1.10 (0.06)
Total K g kg^{-1}	9.80 (0.52)
Total Cd mg kg^{-1}	5.95 (0.27)
Total Pb mg kg^{-1}	167.4 (12.5)
Available N mg kg^{-1}	27.60 (2.47)
Available P mg kg^{-1}	15.25 (1.93)
Available K mg kg^{-1}	78.56 (5.84)
Available DTPA-Cd mg kg^{-1}	0.96 (0.01)
Available DTPA-Pb mg kg^{-1}	33.31(3.58)

** soil suspension (1:2.5), EC = Electrical conductivity and OM = organic matter; Values between practices are standard deviation (SD).*

2.3 Organic Amendments

Three types of organic amendments were used in this study: (1) rice straw (RS), (2) rice straw compost (RSC) and (3) rice straw + farmyard manure compost (RSFC). Rice straw and farmyard manure were obtained from Agronomy and Animal Production Farms, respectively at Faculty of Agriculture, Benha University, Egypt.

2.4 Composting Process

Rice straw was cut to small pieces before starting composting process. Rice straw and rice straw- farm yard manure were divided individually into ten layers and the activated mixture (20 kg ammonium sulfate, 4 kg super phosphate and 2 L EM solution per each ton organic residues) was added between the layers. EM solution was contained different types of active microbes such as bacteria, fungi, actinomycetes and yeast to enhance the decomposition process of organic residues. The water content during composting process was kept at 50-60%. Piles of composts were turned one time every week for aeration. The compositing process was conducted for 12 weeks. The chemical properties of the obtained composts are presented in Table 2.

2.5 Pot Experiment

A pot experiment was conducted from November 1, 2012 to April 15, 2013 in the greenhouse of Soil Science Department, Benha University, Qalyubia Governorate, Egypt. The experiment was organized in a randomized complete block design (RCBD). Ten treatments including the control were performed with three replicates. The chosen organic amendments (RS, RSC and RSFC) were applied at three rates (0.25, 0.5 and 1%). The experimental pots were filled with 4 kg soil and mixed well with the above-mentioned organic amendments individually. Soil moisture of the experimental pots was maintained at 60% of the water-holding capacity (WHC), and then incubated for 15 days in November 1, 2012 to encourage the interaction between the soil and organic amendments. Ten inoculated bean seeds with *R. leguminosarum* were sown in November 15, 2012, and then the soil was directly irrigated with tap water. The bean plants were thinned to 5 plants after 15 days from the sowing. The soil was received an activation dose of nitrogen fertilizer (0.08 g pot^{-1}) in the form of urea (46.6% N). Super phosphate (15% P_2O_5) and potassium sulfate (48% K_2O) were used as sources for P and K at rates of 0.80 g pot^{-1} and 0.20 g pot^{-1}, respectively. Phosphorus fertilizer was mixed with RS, RSC and RSFC amendments and added 15 days before sowing bean seeds. Nitrogen fertilizer was added after thinning bean plants, while potassium fertilizer was applied after 35 days from sowing. The microelements (Cu, Zn, Mn and Fe) were applied three times (after 40 days, 65 days and 90 days from sowing) in the form of sulfate as foliar applications at a rate of 3 g l^{-1} for each element. During the whole experimental period, the soil moisture was kept at 60% of WHC by balancing pots every four days.

2.6 Soil and Organic Amendments Analyses

Soil particle-size distribution was determined by the pipette method [17]. The electrical conductivity (EC) and pH values of soil, RSC and RSFC were determined in suspensions of 1:2.5 (w/v) ratios by pH and EC meters [18]. The organic carbon (OC) of soil, RS, RSC and RSFC were analyzed by potassium dichromate oxidation (1 M) in the presence of sulfuric acid and titrated with ferrous ammonium sulfate (0.5 M) [19]. A factor of 1.72 was used to convert the OC to organic matter (OM). Total concentrations of Ca, Mg, Cd and Pb in soil, RS, RSC and RSFC samples were estimated by the atomic adsorption spectrophotometer after their digestion by a concentrated mixture of H_2SO_4 and $HClO_4$ (ratio of 2:1, v/v). Available N, P and

K were extracted from the soil by KCl (1 M), $NaHCO_3$ (0.5 M, pH= 8.5) and CH_3COONH_4 (1 M, pH= 7) solutions, respectively. Concentrations of available Cd and Pb were determined using atomic adsorption spectrophotometer after their extraction by ammonium bicarbonate-DTPA (AB-DTPA). Briefly, 5 g soil was mixed with 20 ml of 5 mM DTPA and 1 M NH_4HCO_3 and shaken for 2 h at pH 7.6 [20]. Total and available N concentrations were measured by Kjeldahl method, while concentrations of total and available K were analyzed using flame photometer. Total and available concentrations of P were estimated colormetrically [21] by the spectrophotometer.

2.7 Plant Analysis

Faba bean plants were harvested in April 15, 2013 and divided into three parts (straw, seeds and roots). After that, these parts were transferred to the laboratory for chemical analysis. The collected seeds, straw, and roots of bean plants were washed by the distilled water, oven-dried at 60-70°C for 48 h, and finally weighed to determine their dry weights. Straw, seeds and roots of bean were ground by a stainless steel mill. Sub-samples (0.20 g) from seeds, straw and roots of bean were digested individually with a concentrated mixture of H_2SO_4 and $HClO_4$ (ratio of 2:1, v/v) to determine total concentrations of Pb and Cd by the atomic adsorption spectrophotometer.

2.8 Statistical Analysis

Data were statistically analyzed by SPSS version 16.0 (SPSS Inc., Chicago), and the least significant difference (LSD) test was used to evaluate the significant differences between the experimental treatments.

3. RESULTS AND DISCUSSION

3.1 Effect of Organic Residues on Soil Chemical Properties

The effect of rice straw (RS), rice straw compost (RSC) and rice straw-farmyard manure compost (RSFC) on soil chemical properties are presented in Table 3. Addition of RS, RSC and RSFC caused significant changes in soil pH, organic matter (OM) and available P (AP). The results showed that soil pH, OM and AP enhanced significantly with the increase of amendments applied rates. Soil pH increased markedly from 6.85 in the control treatment to 6.91-7.07, 7.12-7.48 and 7.27-7.78 when the soil treated with RS, RSC and RSFC, respectively. Soil organic matter (OM) enhanced by 1.15, 1.31 and 1.46 times, 1.07, 1.19 and 1.33 times, and 1.03, 1.10 and 1.22 times in soil mixed with RS, RSC and RSFC at levels of 0.25, 0.50 and 1%, respectively. Increases from 13.41 mg kg^{-1} to 13.98, 14.35 and 14.63 mg kg^{-1}, 14.46, 15.02 and 15.78 mg kg^{-1}, and 14.87, 15.92 and 17.25 mg kg^{-1} were recorded in AP as results of RS, RSC and RSFC additions at rates of 0.25, 0.50 and 1%, respectively. The highest soil pH values were recorded when the soil received RSFC, whereas the lowest values were found in RS amended soil. The higher increases of soil pH in RSFC treated soil as compared with RS and RSC treated soils could be explained by the higher presence of Ca^{2+} and Mg^{2+} in RSFC amendment (Table 2). The increase of soil pH values after addition of RS, RSC and RSFC was probably resulted from the release of NH_4^+ and the basic cations (Ca^{2+} and Mg^{2+}) during their decomposition in the soil. Moreover, providing OH^- anions during the microbial mineralization of organic amendments could be also used as a logic illustration for increasing soil pH [22].

Owing to the higher presence of total P in RSFC compared with RS and RSC (Table 2), RSFC treatments were responsible for the greater soil AP values. RS amended soil in comparison to RSC and RSFC ameliorated soils contained the greater OM contents due to the larger OC amounts in RS (Table 2). The soil pH and AP values at the studied treatments followed the order: RSFC > RSC > RS, while for OM followed the order: RS > RSC > RSFC. Several studies have been conducted on heavy metals contaminated soils and found that addition of organic amendments led to positive enhancements in soil chemical properties. Incorporation of rice straw at a rate of 23.2 t ha^{-1} in a Cd contaminated soil increased soil pH, OM and available phosphate from 6.04, 29.8 g kg^{-1} and 20.1 mg kg^{-1} in the control to 6.61, 46.2 g kg^{-1} and 34.9 mg kg^{-1}, respectively [13]. Significant increases were shown by 0.1-0.8 units in soil pH after addition of organic amendments (Chinese milk vetch, rice and wheat straw) in paddy soils [8]. There were some studies reported that organic amendments such as cow manure, local farmyard manure and straw had major role in increasing soil pH [23,24]. In a Cd/Pb contaminated soil, application of organic manure had a major role in increasing soil pH [25]. In a sandy soil polluted artificially with 10 mg Cd kg^{-1}, using biosolid (sewage sludge) compost at 20% caused marked increases in soil pH from 7.30 to 7.54 and in organic carbon from 0.30% to 1.78% [26].

3.2 Effect of Organic Residues on Cd and Pb Availabilities

Concentrations of available Pb and Cd in the studied sandy loam soil as affected by RS, RSC and RSFC are shown in Table 4. The results indicated that concentrations of available Cd and Pb considerably decreased due to the addition of RS, RSC and RSFC in the soil. The highest decreases of Pb and Cd availabilities were noticed after treating the soil with RSFC, where the lowest decreases were found due to using RS as an amendment. The decreases of Cd and Pb availabilities were consisted with increasing applied rates of RS, RSC and RSFC. In comparison to the control treatment, application of 0.25% of RS, RSC and RSFC diminished the available amounts of Pb and Cd by 9.94-17.56%, 13.14-27.36% and 19.74-56.76%, respectively. The use of RS, RSC and RSFC at 0.5% lowered availability of Pb by 20.67%, 29.57% and 39.06, and availability of Cd by 27.03%, 51.35 and 86.49%, respectively. When the studied soil was amended by 1% of RS, RSC and RSFC, concentrations of Pb and Cd reduced by 33.80-41.89%, 49.55-71.62%, and 65.06-94.59%, respectively. Concentrations of available Pb and Cd at all studied treatments followed the order: RSFC < RSC < RS < control.

Table 2. Chemical properties of the used organic amendments

Properties	RS	RSC	RSFC
pH *	n.d	7.05 (0.45)	7.58 (0.39)
EC * dS m^{-1}	n.d	1.18 (0.10)	1.67 (0.13)
Total N g kg^{-1}	6.40 (0.41)	9.70 (0.49)	12.9 (1.20)
Total P g kg^{-1}	2.40 (0.12)	3.10 (0.21)	5.20 (0.34)
Total K g kg^{-1}	13.1 (1.27)	16.9 (1.87)	22.5 (2.61)
Total C g kg^{-1}	480.8 (20.3)	358.1(14.3)	274.6 (5.74)
Total Cd mg kg^{-1}	0.01 (0.00)	0.01 (0.00)	0.03 (0.001)
Total Pb mg kg^{-1}	0.03 (0.001)	0.02 (0.00)	0.05 (0.002)
Total Ca g kg^{-1}	14.2 (2.14)	16.5 (1.58)	29.6 (2.97)
Total Mg g kg^{-1}	2.80 (0.19)	3.90 (0.11)	5.80 (0.26)

** soil suspension (1:2.5), n.d = not determined and EC = Electrical conductivity; RS= rice straw, RSC= rice straw compost and RSFC= rice straw-farmyard manure compost. Values between practices are standard deviation (SD)*

Table 3. Soil chemical properties as affected by organic amendments

Organic amendments	Rates	Soil pH *	OM (g kg^{-1})	AP (mg kg^{-1})
Control		6.85 (0.25)	19.6 (1.45)	13.41 (1.12)
RS	R1	6.91 (0.19)	22.6 (1.08)	13.98 (0.58)
	R2	6.98 (0.24)	25.8 (1.11)	14.35 (0.44)
	R3	7.07 (0.21)	28.7 (1.43)	14.63 (0.63)
	Mean	6.99	25.7	14.32
RSC	R1	7.12 (0.22)	21.2 (0.98)	14.46 (0.23)
	R2	7.34 (0.13)	23.3 (1.15)	15.02 (084)
	R3	7.48 (0.20)	26.0 (0.87)	15.78 (0.91)
	Mean	7.31	23.5	15.09
RSFC	R1	7.24 (0.19)	20.3 (1.38)	14.87 (0.71)
	R2	7.56 (0.27)	21.6 (1.21)	15.92 (0.86)
	R3	7.78 (0.11)	24.0 (1.41)	17.25 (0.64)
	Mean	7.53	23.2	16.01
LSD		0.06	0.58	0.41

** soil suspension (1:2.5) R= rate, RS= rice straw, RSC= rice straw compost and RSFC= rice straw- farmyard manure compost. R1, R2 and R3= 0.25, 0.50 and 1% of organic amendments respectively. Control = 0%. AP= available phosphorus and OM= organic matter. Values between practices are standard* deviation *(*SD*)*

Table 4. Available concentrations of Pb and Cd in the sandy loam soil as affected by organic amendments

Organic amendments	Rates	DTPA-Pb (mg kg^{-1})	DTPA-Cd (mg kg^{-1})
Control		29.08 (0.87)	0.74 (0.03)
RS	R1	26.19 (0.53)	0.61 (0.01)
	R2	23.07 (0.46)	0.54 (0.01)
	R3	19.25 (0.94)	0.43 (0.02)
	Mean	22.84	0.53
RSC	R1	25.26 (1.11)	0.54 (0.04)
	R2	20.48 (0.53)	0.38 (0.02)
	R3	14.67 (0.62)	0.21 (0.02)
	Mean	20.14	0.38
RSFC	R1	23.34 (0.91)	0.32 (0.01)
	R2	17.72 (1.03)	0.10 (0.01)
	R3	10.16 (0.45)	0.04 (0.00)
	Mean	17.07	0.15
LSD		2.89	0.02

R= rate, RS= rice straw, RSC= rice straw compost and RSFC= rice straw-farmyard manure compost. R1, R2 and R3= 0.25, 0.50 and 1% of organic amendments respectively. Control = 0%. Values between practices are standard deviation (SD)

Extractable Pb concentrations diminished from 138 mg kg^{-1} to 75.9 mg kg^{-1} and 104 mg kg^{-1} after using green/catering wastes-derived compost and green/catering/ paper wastes-derived compost, respectively [27]. The use of biochar as an organic amendment in Cd and Pb contaminated soil decreased the amounts of available Cd and Pb from about 0.55 mg kg^{-1} and 0.30 mg kg^{-1} to 0.48 mg kg^{-1} and 0.22 mg kg^{-1} [12]. Incorporation of rice straw-manure and pig manure at 10 g kg^{-1} reduced the availability of Pb from 507.1 mg kg^{-1} to 468.3 mg kg^{-1} and 457.9 mg kg^{-1}, respectively [14].

Decreases of Cd and Pb availabilities in our study under RS, RSC and RSFC treatments were probably related to the enhancement of soil pH, OM and AP. Organic materials had an ability to diminish availabilities of heavy metals by complexion and adsorption processes through increasing soil pH and by the specific interaction of metals with the reactive groups in the organic matter [28]. It was reported that the increase of soil pH might activate adsorption of Cd on soil particles and decrease the partition of Cd to soil solution [12-13]. Furthermore, the improvement of soil P content contributed to the immobilization of Cd in the soil. The increase of soil OM and pH might affect the immobilization of metals by organic amendments [29]. Addition of organic residues led to releasing for OH-ions that responsible for the increase of soil pH, and then reducing Pb solubility through forming $Pb(OH)_2$ [12]. Moreover, organic amendments had high capacity to decrease the soluble or exchangeable forms of Cd and Pb through transformation them to immobile forms such as carbonates, Fe/Mn oxides or residual fractions. In our investigation, the highest soil pH and AP values in RSFC treatments (Table 3) could be used as good reasons to explain their largest abilities in the reduction of Cd and Pb motilities. It was clear from our results to approve that pH and AP compare with OM were more important factors for controlling Cd and Pb availabilities in sandy loam soils.

3.3 Effect of Organic Residues on Faba Bean Growth

Data in Table 5 indicated that application of RS, RSC and RSFC caused significant improvements in bean growth (straw, seeds and roots dry weights). Additionally, the enhancements of bean straw, seeds and roots dry weights were considerably depended on increasing their applied rates. Incorporation of RS at rates of 0.25, 0.50, 1% improved dry weights of bean straw, roots and seeds by 1.55-1.69 times, 2.10-2.95 times and 2.08-3.04 times, respectively. The use of RSC enhanced dry weights of bean straw, roots and seeds by 1.63-1.80 times, 2.34-3.51 times and 2.33-3.45 times, while RSFC increased them by 1.73-1.97 times, 2.66-4.11 times and 2.49-3.50 times, respectively at same above-mentioned rates. The dry weights of bean seeds, straw and roots under the chosen amendments followed the order of RSFC > RSC > RS, which were consisted with decreases of Pb and Cd availabilities in the soil.

There were significant increases recorded in straw, grain yields and root biomass of rice from 10.61, 1.14 and 1.47 g pot^{-1} to 35.56-43.85 g pot^{-1}, 14.00-18.59 g pot^{-1} and 5.50-6.12 g pot^{-1} in a Cd/Cu contaminated soil treated with pig manure at 10 and 30 g pot^{-1}, respectively [8]. Application of different green wastes and municipal solid wastes-derived composts improved the shoot growth of *Agrostis capillaris* from about 0 g pot^{-1} in the control to 2.2 and 6.9 g pot^{-1}, respectively [27]. The used amendments in our study significantly declined Cd and Pb availabilities (Table 4) and then altered their hazardous effects on bean plants, which were expressed in the dry weights of their straw, roots and seeds. The control treatment yielded the lowest growth of bean due to the highest accumulation of available Cd and Pb in the soil. It was recorded in many studies that excessive presence of Cd and Pb in the soil could negatively influence the growth and development of roots system, photosynthesis and yield of crops [30-33].

3.4 Effect of Organic Residues on Pb and Cd Uptake

Table 6 showed the effect of RS, RSC and RSFC on accumulations of Cd and Pb in different parts of bean (straw, seeds and roots). The results indicated that RS, RSC and RSFC had high efficiency in decreasing absorptions of Pb and Cd by straw, seeds and roots of bean, especially at their highest addition rates. The roots of bean accumulated the highest amounts of Pb and Cd, whereas the seed contained the lowest values. The concentrations of Pb in bean straw decreased from 21.80 mg kg^{-1} in the control to 19.7, 18.1 and 16.7 mg kg^{-1}, while in the case of Cd, these values decreased from 3.49 mg kg^{-1} in the control to 2.83, 2.27 and 1.76 mg kg^{-1} at 0.25% of RS, RSC and RSFC, respectively. With increasing rates of RS, RSC and RSFC to 1%, concentrations of Pb and Cd in bean straw decreased to 12.3-1.81 mg kg^{-1}, 9.25-1.07 mg kg^{-1} and 4.88-0.21 mg kg^{-1}, respectively. The reduction percentages of Pb in bean seeds were 22.01, 37.99 and 51.01%, while for Cd were 17.53, 30.93 and 56.70% due to the application of 0.25% of RS, RSC and RSFC, respectively. These values in the case of bean roots were 6.41, 17.55 and 25.07% for Pb, and were 22.11, 33.64 and 45.35% for Cd under the above-mentioned conditions. At the highest rates of RS, RSC and RSFC (1%), concentrations of Pb and Cd lowered by 58.93-50.52%, 79.32-84.54%, and 96.11-98.96% in bean seeds, while in bean roots, these values reduced by 21.17-47.58%, 43.73-67.47%, and 49.58-83.83%, respectively. The present study indicated that higher concentrations of total and available Pb compared with those of Cd in the soil (Table 1) could be responsible for larger accumulations of Pb in straw, seeds and roots of bean.

Table 5. Dry weights of bean straw, seeds and roots as affected by organic amendments

Organic amendments	Rates	Straw (g pot^{-1})	Seeds (g pot^{-1})	Roots (g pot^{-1})
Control		14.73 (0.84)	1.46 (0.87)	2.71 (0.87)
RS	R1	22.86 (0.67)	3.07 (0.10)	5.64 (0.14)
	R2	23.78 (0.90)	3.59 (0.12)	6.86 (0.19)
	R3	24.92 (0.96)	4.31 (0.07)	8.23 (0.20)
	Mean	23.85	3.66	6.91
RSC	R1	23.95 (1.54)	3.41 (0.08)	6.28 (0.11)
	R2	24.90 (1.09)	4.30 (0.06	7.64 (0.09)
	R3	26.58 (1.43)	5.12 (0.09)	9.35 (0.17)
	Mean	25.14	4.28	7.76
RSFC	R1	25.42 (0.77)	3.88 (0.10)	6.76 (0.21)
	R2	27.04 (0.93)	4.90 (0.12)	8.28 (0.24)
	R3	28.99 (1.21)	6.00 (0.05)	9.49 (0.30)
	Mean	27.15	4.93	8.18
LSD		1.18	0.58	0.82

R= rate, RS= rice straw, RSC= rice straw compost and RSFC= rice straw-farmyard manure compost. R1, R2 and R3= 0.25, 0.50 and 1% of organic amendments respectively. Control = 0%. Values between practices are standard deviation (SD)

Table 6. Accumulations of Pb and Cd in straw, seeds and roots of beans as affected by organic amendments

Organic amendments	Rates	Straw		Seeds		Roots	
		Pb (mg kg^{-1})	Cd (mg kg^{-1})	Pb (mg kg^{-1})	Cd (mg kg^{-1})	Pb (mg kg^{-1})	Cd (mg kg^{-1})
Control		21.80 (1.41)	3.49 (0.17)	7.45 (0.87)	0.97 (0.87)	35.90 (0.87)	5.38 (0.87)
RS	R1	19.70 (0.97)	2.83 (0.09)	5.81 (0.16)	0.80 (0.05)	33.60 (2.14)	4.19 (0.13)
	R2	16.60 (1.01)	2.16 (0.12)	4.53 (0.21)	0.64 (0.01)	30.40 (2.66)	3.75 (0.26)
	R3	12.30 (0.83)	1.81 (0.24)	3.06 (0.11)	0.48 (0.01)	28.30 (1.84)	2.82 (0.09)
	Mean	16.20	2.27	4.47	0.64	30.77	3.59
RSC	R1	18.10 (0.54)	2.27 (0.15)	4.62 (0.14)	0.67 (0.02)	29.60 (1.56)	3.57 (0.11)
	R2	14.30 (0.47)	1.55 (0.13)	3.17 (0.12)	0.39 (0.01)	25.90 (1.70)	2.96 (0.07)
	R3	9.25 (0.29)	1.07 (0.09)	1.54 (0.09)	0.15 (0.01)	20.20 (1.15)	1.75 (0.09)
	Mean	13.88	1.63	3.11	0.40	25.23	2.76
RSFC	R1	16.70 (0.98)	1.76 (0.02)	3.65 (0.05)	0.42 (0.02)	26.90 (2.05)	2.94 (0.18)
	R2	11.50 (0.78)	0.93 (0.04)	1.86 (0.06)	0.18 (0.01)	21.30 (1.52)	2.15 (0.08)
	R3	4.88 (0.27)	0.21 (0.01)	0.29 (0.02)	0.01 (0.01)	18.10 (0.98)	0.87 (0.03)
	Mean	11.03	0.97	1.93	0.20	22.10	1.99
LSD		1.51	0.17	0.46	0.09	2.07	0.29

R= rate, RS= rice straw, RSC= rice straw compost and RSFC= rice straw-farmyard manure compost. R1, R2 and R3= 0.25, 0.50 and 1% of organic amendments, respectively. Control = 0%. Values between practices are standard deviation (SD)

Significant decreases were found in Pb uptake by shoots of spinach, cabbage, and legume grasses after incorporation of organic amendments such as peat and compost [34]. The immobilization of heavy metals in the contaminated soil by cost-effective amendments such as manure was studied and the results showed that Cd and Pb concentrations in shoots of white lupin lowered by 60.1% and 52.0%, respectively [25]. The use of active carbon and biochar as organic amendments decreased concentrations of Cd in rapeseed by 31% and 23%, respectively in comparison to the control [12]. Organic amendments were generally decreased Pb uptake by Chinese cabbage, and the lowest concentrations of Pb in cabbage shoots (3.5 mg kg^{-1}) and roots (6.9 mg kg^{-1}) were recorded after the addition of 30 pig manure in a soil polluted with 600 mg Pb kg^{-1} [14]. In our study, the probable alterations of Cd and Pb from available forms to insoluble forms through their reactions with the OH^- and PO_4^- ions during the decomposition (mineralization) of RS, RSC and RSFC in the soil could be responsible for diminishing Cd and Pb accumulations in bean tissues. RSFC had higher effectiveness compared with RS and RSC in decreasing Cd and Pb absorptions by bean parts (straw, seeds and roots) due to its greater ability in reducing Cd and Pb availabilities in the soil (Table 4).

4. CONCLUSION

Our results concluded that organic amendments (RS, RSC and RSFC) succeeded in the remediation of the chosen contaminated sandy loam soil and in improving bean growth. Soil pH, OM and AP increased as results of RS, RSC and RSFC incorporation and this might decrease availabilities of Cd and Pb in the soil. The increase of applied RS, RSC and RSFC rates had significant effects in diminishing concentrations of available Cd and Pb and their uptake by bean tissues. Concentrations of Cd and Pb in straw, seeds and roots of bean were highly influenced by the available presence of Cd and Pb in the soil. Availabilities of Cd and Pb in the soil should be considered in predicting their concentrations in plants. Based on our results, RS, RSC and RSFC at rates of 1% should be recommended to ameliorate the contaminated sandy loam soil. The RSFC was more resourceful and commercial amendment than RS and RSC in decreasing Cd and Pb availabilities and then reducing their absorptions by bean. Field experiments should be conducted to evaluate the short and long-terms effects of RS, RSC and RSFC on the growth of different crops and accumulations of heavy metals in their tissues in contaminated soils. At the end, the author would like to thank Soil and Water Department at Faculty of Agriculture, Benha University, Egypt (http://www.fagr.bu.edu.eg and http://www.bu.edu.eg) for their useful support during the experimental work.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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