The effect of interaction between Cd x Single Super Phosphate on Radish

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Abstract

A field experiment was conducted to find out "The effect of interaction between Cd × Single Super Phosphate on Radish. The soil used was alluvial collected (Texture: Silty Clay Loam, Clay: 36.6%, CEC: 20.6 Coml.(p+) kg^{-1}) Organic C:0.50% and DTPA-Cd 0.37 ppm. Initial pH of the soil was 7.6 which increased to 7.7 ofter irrigation. Plastic pots (each containing 5 kg of soil) were used. Radish was grown as test crop. Cd was applied as $CdCO_3$ to provide Cd at the rate of 0, 5 and 10 mg kg^{-1} and Ca was applied as SSP at the rate of 0,20 and 40 g kg^{-1} soil with three replication of each treatment. The pot was well placed on the alluvial soil of Sheila Dhar Institute Experimental Farm, Allahabad. Three levels of single super phosphate (0, 200 and 400 kg ha^{-1}) and Cd (0, 5 and 10 ppm) were applied as SSP and $CdCl_2$, respectively. Addition of 400 kg ha^{-1} SSP increased the maximum leaf dry biomass and root yield of Radish by 28.46% and 16.96% over the control respectively. The application of 10 ppm Cd maximum reduced dry biomass yield of Radish by 16.38% compared tocontrol and registered the highest accumulation of Cd in leaf and root of Radish by 1.42 ppm and 3.26 ppm respectively. Therefore, 200 kg ha^{-1}SSP applications may be recommended to enhance biomass yield of *Raphanas sa*tiva,The response of single super phosphate was observed ameliorative in Cd-contaminated plots.

Key words: *Cadmium, Single super phosphate, Radish*

Introduction

Pollution of the biosphere by toxic metals has accelerated severely since the beginning of the industrial revolution. The primary sources of metal pollution include the burning of fossil fuels, mining and smelting of metaliferous ores, municipal wastes, fertilizers, pesticides and waste water irrigation. Contamination of groundwater and soil by heavy metals leads to major environmental and human health problems. Plant metabolism is also affected negatively by the heavy metals (1).

Cadmium (Cd) levels in arable land have increased during the last century due to anthropogenic activities. Most of the Cd transferred to humans comes from food, especially plant food. Carrots are of particular concern due to a large consumption of this vegetable. In the body, Cd is stored and may disturb essential functions and cause diseases and organ failure (2).

According to estimations 3 to 5% of the Cd in the food is absorbed during digestion (3). In the body the absorbed Cd is bound to a protein (metallothionein) in the liver. Some of these complexes leach to the kidney where Cd is accumulated in the kidney cortex (Arbetsoch, 2009). The highest concentration in the liver is reached at an age of 20 to 25 and in the kidney between 50 and 60 (3). After that, the concentration slightly decreases.

Phosphate (P) fertilizers induced immobilization of heavy metals Pb, Cd, and Zn. Single super phosphate (SSP) was more effective in reducing Pb bioavailability than PR but had variable effects on Zn bioavailability. The level of P fertilizers at application rate of 300 g/m^2 was enough to reduce metals availability in the soil (with a reduction of up to 79% in WE Pb) and phytoability (up to 47% in V-Pb) at the first stage of remediation. Cd uptake by cabbage was a complex process and it should be careful to evaluate the impact of phosphate application on cadmium availability in soil. SSP application must be carefully designed to reduce Zn mobilization and co-application of liming materials with SSP may be necessary to offset potential soil acidification (4). The objectives of this study were to examine the effect of single super phosphate on the uptake of Cd and the effects on their respective concentration in roots yield and leafs dry biomass of *Raphanus sativus.*

Plant Material and Experimental Layout

The Sheila Dhar Institute experimental site covering an area of 1 hectare located at Allahabad in northern India at 25º57' N latitude, 81º50'E longitude and at 120±1.4 m altitude. A sandy clay loam soil, derived from Indo-Gangetic alluvial soils, situated on the confluence of rivers Ganga and Yamuna alluvial deposit, was sampled for the study. The texture was sand (>0.2 mm) 55.54%, silt

(0.002-0.2 mm) 20.32% and clay (<0.002 mm) 24.25%. The detailed physico-chemical properties of the investigated soil have been given in the Table 1

Table-1. Physico-chemical properties of the Sheila Dhar Institute (SDI) Experimental Farm, Allahabad, India

Parameters	Values
Texture: Sandy Clay Loam (Sand, Silt and Clay %)	(55.54,20.32 and 24.25, respectively)
Ph	7.8
EC(dSm^{-1}) at 25^0C	0.28
Organic Carbon (%)	0.56
CEC [C mol (p^+) kg^{-1}]	19.8
Total Nitrogen (%)	0.08
Total Phosphate (%)	0.07
DTPA-extractable Cd (ppm)	0.26

Experimental

After systematic survey factorial experiment was conducted to study the effect of single super phosphate on the uptake of cadmium by Radish (*Raphanus raphanistrum* subsp. *sativus*). The experiment was replicated thrice with nine treatments and conducted in completely factorial randomized block design (factorial RBD). After 24 hr of the treatment seeds were sown. Soil moisture was maintained by irrigating the crops at interval of 5-6 days. Radish was grown successively in the 27 plots (each of $1m^2$ in area). The treatments of Cd × SSP relationship consisted of 0, 100 and 200 kg ha^{-1} single super phosphate along with 0, 5 and 10 ppm Cd. The source of Cd and phosphate were $CdCl_2$ and SSP respectively. The crop was harvested at 60 days after sowing (DAS).The treatment combinations were as follows:
(1) A_0B_0 (Control), (2)A_1B_0 [Low dose of cadmium (5ppm Cd)], (3)A_2B_0 [High dose of Cadmium (10ppm Cd)], (4)A_0B_1 [Low dose of SSP (100 kg/ ha)], (5)A_0B_2 [High dose of SSP (200 kg/ha)], (6)A_1B_1 [Low dose of Cadmium and SSP (5 ppm Cd along with 100 kg/ha SSP)], (7)A_1B_2 [Low dose of Cadmium (5 ppm) and High dose of SSP (200 kg/ha)],
(8). A_2B_1 [High dose of Cadmium (10 ppm) and Low dose of SSP (100 kg/ha)], (9). A_2B_2 [High dose of Cadmium and SSP (10 ppm Cd along with 200 kg/ha SSP)].

Soil Sampling

The larger fields were divided into suitable and uniform parts and each of these uniform parts was considered a separate sampling unit. In each sampling unit, soil samples were drawn from several spots in a zigzag pattern, leaving about 2 m area along the field margins. Silt and clay were separated by Pipette method and fine sand by decantation (5).
Extraction for Cadmium (Cd) Content in Soil
For total Cd content, one gram of soil was mixed in 5 ml of HNO_3 (16M, 71%) and 5 ml of $HClO_4$ (11 M, 71%). The composite was heated up to dryness. The volume was made up to 50 ml with hot distilled water. The samples were filtered using Whatman filter paper 42 (42.5mm). The clean filtrate was used for the estimation of cadmium using Atomic Absorption Spectrophotometer (AAS) (AAnalyst600, PerkinElmer Inc., MA, USA) (6).

Soil Physico-chemical Analysis

Soil pH was measured with 1:2.5 soil water ratio using Elico digital pH meter (Model LI 127, Elico Ltd., Hyderabad, India). Double distilled water was used for the preparation of all solutions. Organic carbon was determined by chromic acid digestion method, cation exchange capacity (CEC) by neutral 1 N ammonium acetate solution, total nitrogen by digestion mixture (containing sulphuric acid, selenium dioxide and salicylic acid) using micro-Kjeldahl method, Glass Agencies, Ambala, India. Total phosphorus by hot plate digestion with HNO_3 (16M, 71%) and extraction by standard ammonium molybdate solution (5,6).

Plant Analysis
Plants were harvested after 60 days having higher phytochemicals at their maturity stage as suggested by Mani et al. (7). Samples were carefully rinsed with tap water followed by 0.2 % detergent solution, 0.1N HCl, de-ionized water, and double distilled water.
Samples were dried in a hot-air oven at a temperature of 60 ºC and grinded to fine powder. Plant dry biomass weight was recorded.One gram of ground plant material was digested with 15 ml of tri-acid mixture (6) containing conc. HNO_3 (16M, 71%), H_2SO_4 (18M, 96%) and $HClO_4$ (11M, 71%) in 5:1:2), heated on hot plate at low heat (60ºC) for

Cd-rate (ppm)	SSP kg ha^{-1}	Root Yield	Leaf Dry biomass	Cd concentration (ppm)	
				Root	Laef
0	0 100 200	18.16 20.56 21.24	12.65 15.72 16.25	0.26 0.21 0.14	0.10 0.12 0.08
5	0 100 200	17.96 20.25 20.76	12.12 15.48 16.12	1.65 0.96 0.28	0.25 0.32 0.21
10	0 100 200	17.56 20.12 20.45	10.87 13.78 15.67	3.26 1.54 0.31	1.42 0.93 0.27
SE=		0.74	0.65	0.20	0.019
CD=		1.57	1.38	0.42	0.039

30 minutes and cadmium was determined by the Atomic Absorption Spectrophotometer (Analyst 600, PerkinElmer Inc., MA, USA).

Statistical Analysis

Data was analyzed by factorial analysis of variation (ANOVA) using various treatments as independent factors with the help of the sum of square (SS) and degree of freedom (DF). The standard error (SE) is given by $SE = \sqrt{\frac{2V_E}{n}}$, where, V_E is the variance due to the error, n is the number of replications, and the critical difference (CD) is given by CD = $SE_{diff.} \times t_{5\%}$ ($t_{5\%}$= 2.042 at DF_{error}= 30 was observed) and standard deviation (SD) were determined in accordance with (8).

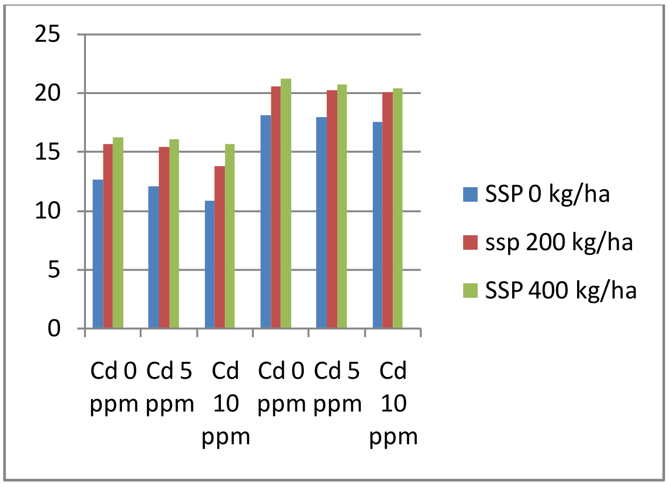
Effect of Cd × SSP interaction on root yield and leaf dry biomass of Radish (*Raphanus raphanistrum* subsp. *sativus*)

The data presented in table 2 and fig. 1 revealed that Cd and SSP were observed significant on influencing the dry biomass and root yield of Radish (*Raphanus raphanistrum* subsp. *sativus*). Application of SSP @ 200 kg ha^{-1} at different levels of Cd (0, 5 and 10 ppm) treated plots produced root yield of 21.24, 20.76 and 20.45q/ha, resulted in 16.96%, 14.32% and 12.61% increase over thecontrol plots, respectively. Similarly application of SSP @ 200 kg ha^{-1} at the aforesaid levels of Cd treated plots produced leaf dry biomass of 16.25, 16.12 and 15.67 q/ha, resulted in 28.46%, 27.43% and 23.87% increase over the control plots, respectively (7,9).

The combined application of 10 ppm Cd along with 100 kg ha^{-1} SSP also enhanced the root yield and leaf dry biomass production which were observed 20.12 and 13.78q/ha, resulted in 10.79% and 8.93% increase over the control, respectively, indicating ameliorative role of SSP addition in plots. The application of Cd at 10 ppm registered the minimum root yield and leaf dry biomass up to 17.56 and 10.87q/ha showing maximum retardation in growth to the extent of 3.42% and 16.38% respectively over the control due to the presence of excess Cd in the root environment (4,9).

Table 1: Effect of Cd × SSP interaction on root yield and leaf dry biomass (q/ha) and Cd concentration (ppm) of Radish (*Raphanus raphanistrum* subsp. *sativus*)

Fig. 1: Effect of Cd × SSP interaction on leaf dry biomass and root yield of Radish (*Raphanus raphanistrum* subsp. *sativus*)



Leaf dry biomass

Root yield

Effect of Cd × SSP interaction on Cd concentration in leaf and root of Radish (*Raphanus raphanistrum* subsp. *sativus*)

The data (Table 2) indicated that the effect of Cd, SSP and Cd × SSP interaction were observed significant. Accumulation of Cd in roots and leaf of plants significantly increased and indicated greater relative Cd accumulation from control to Cd added plots. Application of 10 ppm Cd of maximum increased the accumulation of Cd leaf and root of Radish (*Raphanus raphanistrum* subsp. *sativus*) by 1.42 and 3.26 ppm, respectively (Fig. 2 and 3). Application of Cd 10 ppm+ SSP 200 kg ha^{-1} (T_9) decreased the accumulation of Cd 0.27 ppm and 0.31 ppm in leafs and root of Radish (*Raphanus raphanistrum* subsp. *sativus*) compared to non-amended plot, respectively.Added single doses of SSP 200 kg ha^{-1} reduced minimum the leaf and root Cd uptake of *Raphanus sativus* by 0.08 and 0.14compared to control plots, respectively (10,4).

The addition of P may reduce Cd phytoavailability through a combination of several mechanisms, such as sorption (including phosphate-induced Cd adsorption and surface complexation), precipitation, or co-precipitation (4,11,12). However, there were no Cd phosphate minerals formed freshly by the end of experiment identified with XRD (Ma et al., 1994), and it was speculated that a solid residue containing Cd was Ca-Cd phosphate or Ca Pb-Cd phosphate (13). Chen (14) suggested that reduction in aqueous Cd concentrations with apatite addition occurred primarily because of sorption mechanisms, such as surface complexation and ion exchange rather than precipitation of Cd phosphate.

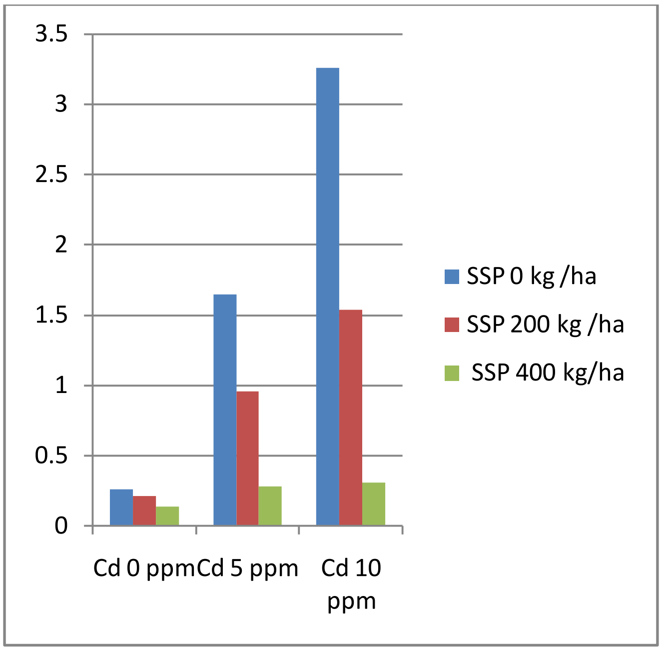


Fig. 2 : Effect of Cd × SSP interaction on Cd concentration in leaf of Radish (*Raphanus raphanistrum* subsp. *sativus*) (ppm)

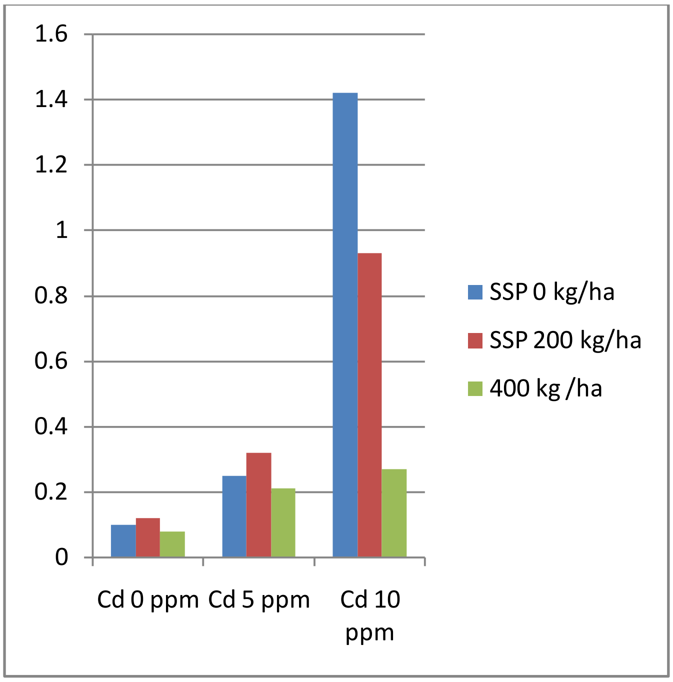


Fig. 3: Effect of Cd × SSP interaction on Cd concentration in leaf of Radish (*Raphanus raphanistrum* subsp. *sativus*) (ppm)

Heavy metals are mobile and can be taken up easily by the plants. They occur in the soil in soluble form as salts (15). However, only soluble, exchangeable and chelated metallic species in the soil are mobile and in available form (16). Mobility is an important factor in regulating the availability and solubility of heavy metals in the soil and soil solution. The mobility depends on their speciation in the soil, which in turn depends on parameters such as organic matter and mineral composition and pH of the soil (17). Mobility of heavy metals is also related to their immobilization in the solid soil. Metal accumulation in plant depends on plant species, growth stages and types of soil and metal, soil conditions, weather and environment (18).

Single super phosphate treated plots registered the highest leaf dry biomass and root yield of Radish (*Raphanus sativus*)28.46% and 16.96%respectively. Application of SSP @ 200 kg ha^{-1} was found most effective in boosting the leaf dry biomass and root yield of Radish. Cd @ 10 mg kg^{-1} influenced the leaf dry biomass and root yield diminutively, which was recorded 16.38 % and 3.42% decrease over the control plots, respectively in *Raphnas sativa* .

The reduced uptake of Cd was observed in single super phosphate treated plots. An ameliorative effect of single super phosphate was observed in Cd-contaminated soil. The results of presented study showed that single super phosphate can effectively immobilize Cd in the soil. Single super phosphate has potential to reduce Cd accumulation in both root and leaf of the *Raphanas sativa*.

The application of single super phosphate to the soil possibly reduces Cd in the edible parts of the plants and helps to reduce the risk to the health of people living in metal contaminated areas. A more detailed study is required to grow *Raphanas sativa* or other vegetable crops in metals-contaminated areas and evaluate their growth and distribution of heavy metals in different edible parts of plants.

In view of the uncertainties that remain about the behavior and effects of Cd in the food chain, it is desirable to minimize its concentration in crops that are grown on sewage- irrigated soils.

As the uptake of Cd is reduced in presence of single super phosphate, a clear antagonism takes place. The addition of single super phosphate is bound to decrease the uptake of Cd by the *Raphanas Sativa* .Where there is an access of industrial effluent rich in Cd, such amendments can be of practical value.

Authors are grateful to Dr. AlokLehri, Incharge, CIF Division, National Botanical Research Institute ,Lucknow for analyzing soil and plant samples for heavy metals by A.A.S. (AAnalyst600, PerkinElmer Inc., MA, USA).

References

1. Singh, A. and Agrawal, M., 2010. Effects of municipal waste water irrigation on availability of heavy metals and morpho–physiological characteristics of *Beta vulgaris* L., *J. Environ. Biol.* 31: 727–736
2. Holmkvist A., 2009. Effect of Master project in the Horticultural Science Program, 30 ECTS.
3. Arbets- ochmiljömedicin, Akademiskasjukhuset Uppsala. 2009. Homepage[online] Available from:http://www.ammuppsala.se/default.asp?headId=7&pageId=348&subMenuOne=153.
4. Biling WANG, ZhengmiaoXIE, Jianjun CHEN, Juntao JIANG and QiufengSU, 2008. Effects of field application of phosphate fertilizers on the availability and uptake of lead, zinc and cadmium by cabbage (Brassica chinensis L.) in a mining tailing contaminated soil. Journal of Environmental Sciences 20: 1109–1117.
5. Chopra, S.L. and Kanwar, J.S., 1999. Analytical Agricultural Chemistry, Kalyani Publication, New Delhi.
6. Kumar, C. and Mani, D., 2010. Enrichment and management of heavy metals in sewage-irrigated soil. Lap LAMBERT Acad. Publishing, Dudweiler (Germany).
7. Mani, D., Sharma, B., Kumar, C., Pathak, N. and Balak, S., 2012. Phytoremediation potential of *Helianthus annuus*L in sewage-irrigated Indo-Gangetic alluvial soils. Int. J. Phytoremediat., 14(3), 235–246.
8. Motulsky H. J. and Christopoulos A., 2003. GraphPad Software Inc, San Diego CA.
9. Mani D., Shiv Balak, Niraj Kumar Patel, Vishv Kumar Mourya and Neeraj Pal 2014. Effect of compost and single super phosphate on the uptake of cadmium by Radish (*Raphanussativus* L.)
10. Chen, S.B. and Zhu, Y.G., 2004. Effect of different phosphorus-compounds on Pb uptake by Brassica Oleracea. Acta Scientiae Circumstantiae, 24(4):707-712.
11. Laperche V and Traina S J, 1998. Immobilization of Pb by hydroxyapatite. In: Adsorption of Metals by Geomedia: Variables, Mechanisms, and Model Applications (Everett J. A., ed.). London, UK: Academic Press, 255–276.
    12. Valsami-Jones E, Ragnarsdottir K V, Putnis A, Bosbach D, Kemp A J andGressey G, 1998. The dissolution of apatite in the presence of aqueous metal cations at pH 2–7. ChemGeol, 151: 215–233.
12. Ma Q Y, Logan T J andTraina S J, 1994. Effects of Al, Cd, Cu, Fe(II), Ni and Zn on Pb2+ immobilization by hydroxyapatite. Environ SciTechnol, 28: 1219–1228.

13. Chen X B, Wright J V andConca J L, 1997. Effects of pH on heavy metal sorption on mineral apatite. Environ Sci.Technol, 31: 624–631
14. Bloemen, M.L., Markert B.and LeithH., 1995. The distribution of Cd, Cu, Pb and Zn in top soils of Osnabruk in relation to land use. Sci. Total Environ., 166: 137-148.
15. Arambarri, R., R. Garcia and E. Millan, 1999. Relationships between metal contents in soil and grass contaminated by different anthropogenic sources. Toxicol. Environ. Chem., 72: 221-231.
16. 17.Boisson, J., MenchM., VangronsveldJ., RuttensA., Kopponen P. and Koe T.D., 1999. Immobilization of trace metals and arsenic by different soil additives: Evaluation by means of chemical extractions. Commun. Soil Sci. Plant Anal., 30: 365-387.
17. ZalidisG., Barbayirinis N. and MatsiM.T., 1999. Forms and distribution of heavy metals in soils of the Axios Delta of Northen Greece. Commun. Soil. Sci. Plant Anal., 30: 817-827.
18. Kumar M., Sridevi K. and Tamilarasan R., 2012. Assessment of cadmium and its impact on the uptake efficiency of Phosphate fertilizers by Amaranthustricolor. J. Mater. Environ. Sci. 3 (5) 947-954.