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Impact of single super phosphate on the uptake of cadmium by Carrot (*Daucus carota* L.)

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ABSTRACT

A field experiment was conducted to find out the impact of single super phosphate (SSP) on the uptake of cadmium by Carrot (Daucus carota L.) on the alluvial soil of Sheila Dhar Institute experimental farm, Allahabad, Uttar Pradesh. Four levels of SSP (0, 100, 150 and 200 kg ha^{-1}) and Cd (0, 5, 10 and 15 mg kg^{-1}) were applied as SSP and $CdCl_2$, respectively. The application of SSP 200 kg ha^{-1} increased the dry biomass of Carrot by 26.50% over the control. The application of 15 mg kg^{-1} Cd maximum reduces dry biomass of Carrot by 17.70% compared to control and registered the highest accumulation of Cd in shoot and root of Carrot by 1.80 and 2.56 mg kg^{-1}, respectively. Application of Cd 10 mg kg^{-1} + SSP 200 kg ha^{-1} decreased maximum bioaccumulation factor (BFs) of Cd 0.055 in Carrot, compared to non-amended plot. Therefore, 200 kg ha^{-1} SSP application may be recommended to enhance dry biomass of Carrot. The response of SSP was observed ameliorative in Cd-contaminated plots.

Key words: Cadmium, Single Super Phosphate, Carrot, Uptake.

I. INTRODUCTION

Soil pollution by heavy metals is a global environmental problem as it has affected about 235 million hectares of arable land worldwide (Giordani et al., 2005; Bermudez et al., 2012). Cadmium (Cd) is common toxic heavy metal in the environment and general public is exposed to them through the ambient air, drinking water, food, industrial materials and consumer products (Nordberg et al., 2011: Zhai et al., 2015).

Cadmium (Cd) is a trace element that is naturally present in soils. It can also be introduced into soil through anthropogenic activities such as fertilization, irrigation, pesticide application, organic waste disposal and atmospheric deposition (Alloway and Steinnes, 1999; Sheppard et al., 2009). Cadmium is listed as one of the 7th most hazardous substances that can cause potential threat to human health due to its known or suspected toxicity by Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of year 2011(ATSDR, 2011). Cadmium is a human carcinogenic element that affects human cardiovascular, neurological, renal, respiratory, gastrointestinal and reproductive functions (ATSDR, 2011).

Most of trace elements are persistent in soil because of their relative immobility in soils. However, Cd is known as more mobile and soluble than other trace elements. Cadmium enters human body from environment through ingestion via food (especially plant based food) mechanism (Krishnamurti et al., 1999; Vig et al., 2003). Cadmium is present in plant materials due to its uptake from soil (McLaughlin & Singh, 1999). The availability of Cd in soil and its uptake by plant depend on several soil and plant factors. The application of soil amendments to immobilize heavy metals is a promising technology to meet the requirements for environmentally sound and cost-effective remediation (Gupta et al., 2007). The objectives of this study were to examine the impact of single super phosphate on the uptake of Cd and Pb, and the effects on their respective concentration in roots and shoots dry biomass of Carrot.

II. MATERIALS AND METHODS

A. *Plant Material and Experimental Layout*

The Sheila Dhar Institute experimental farm, covers an area of 1 hectare, is located at Allahabad in northern India at 25°57' N latitude, 81°50'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 (mg kg^{-1})	0.05
DTPA-extractable Pb (mg kg^{-1})	0.31

After systematic survey experiment was conducted to study the impact of single super phosphate on the uptake of cadmium by Carrot (*Daucus carota* L.). The experiment was replicated thrice and conducted in completely randomized block design following sixteen treatments. Total 48 plots (having 16 treatments replicated thrice) were installed. There were 48 plots, each plots having ($1\times1m^2$ area). After 24 hr of the treatment seeds were sown in month of October I^{st} week. Soil moisture was maintained by irrigating the crops at interval of 5-6 days. Vegetables were harvested at 75 days after sowing (DAS). Each interaction was made with a heavy metals (having four doses: A_0, A_1, A_2 and A_3) and an ameliorants (having four doses: B_0, B_1, B_2 and B_3). The treatments of Cd × SSP relationship consisted of 0,100, 150 and 200 kg ha^{-1} single super phosphate along with 0, 5, 10 and 15 mg kg^{-1} Cd. The source of Cd and phosphate were $CdCl_2$ and SSP respectively. The interaction study was conducted at Sheila Dhar Institute experimental farm. In the experimental layout diagram 'A' stand for heavy metal (Cd) and 'B'stand for ameliorants (SSP). The treatment combinations have been mentioned under Table 2.

B. *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 (Chopra and Kanwar, 1999).

C. Extraction for Cadmium Content in Soil

For total cadmium 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 (Cd) using Atomic Absorption Spectrophotometer (AAS) (AAnalyst600, PerkinElmer Inc., MA, USA) (Kumar and Mani, 2010).

D. 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) at authors' laboratory. 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 (Chopra and Kanwar 1999; Kumar and Mani 2010).

E. Plant analysis

Crop was harvested after 75 days. 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 ground to a fine powder. Plant dry biomass weight was recorded. One gram of ground plant material was digested with 15 ml of tri-acid mixture (Kumar and Mani, 2010) 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 30 minutes and cadmium (Cd) were determined by the Atomic Absorption Spectrophotometer (AAnalyst600, PerkinElmer Inc., MA, USA).

F. Bioaccumulation Factor

Bioaccumulation factor (BF), defined as the ratio of chemical concentration in a plant (root and shoot tissues) to soil, is used to measure the effectiveness of a plant in concentrating pollutant into aerial part (Fayiga et al., 2004; Sun et al., 2011). Bioaccumulation factor (BFs) is calculated according to the following formula.

$$BFs = \frac{M_{shoot}}{M_{soil}}$$

Where, M_{shoot} is the metal content (mg kg^{-1} dry wt) in shoots, M_{soil} is the total metal content (mg kg^{-1}) in the soil. M_{soil} was calculated by adding total metal content in soil naturally with applied metal content in soil.

G. Statistical Analysis

Data were 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 $SE = \sqrt{\frac{V_E}{}}$, 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 (Motulsky and Christopoulos, 2003).

III. RESULTS AND DISCUSSION

A. Effect of Cd × SSP interaction on dry biomass yield of Carrot

The data presented in the Table-2 indicated that single application of 200 kg ha^{-1} SSP produced maximum dry biomass of Carrot up to the extent of 498 g $plot^{-1}$, which were recorded 26.50% increase over the control plot. Application of 200 kg ha^{-1} SSP at different levels of Cd (5, 10 and 15 mg kg^{-1}) treated plots produced dry biomass of Carrot 489, 427 and 416 g $plot^{-1}$, resulted in 24.22%, 8.47% and 5.67% increase over the control plots. The present study clearly showed ameliorative role of SSP on the dry biomass yield of Carrot. Almost similar findings also reported by Putwattana et al., 2015; Mani et al., 2014a; Kumar et al., 2012; Tang et al., 2015. The application of Cd @ 15 mg kg^{-1} registered the minimum dry biomass of Carrot up to 324 g $plot^{-1}$ showing maximum retardation in growth to the extent of 17.70% compared the control due to the presence of excess Cd in the root environment. Biling et al., 2008; Tang et al., 2011; Mani et al., 2014b; Putwattana et al., 2015 has also reported similar findings.

TABLE-2: Effect of Cd × SSP interaction on dry biomass yield of Carrot (g $plot^{-1}$)

Treatments Symbols	**Treatments (Cd mg kg^{-1}) and SSP (Kg ha^{-1})**	**Replication**			
		R_1	**R_2**	**R_3**	**Mean**
A_0B_0	Cd 0 + SSP 0	417	372	392	393.7
A_0B_1	Cd 0 + SSP 100	434	462	496	464.0
A_0B_2	Cd 0 + SSP 150	476	453	505	478.0
A_0B_3	Cd 0 + SSP 200	534	464	496	498.0
A_1B_0	Cd 5 + SSP 0	409	385	367	387.0
A_1B_1	Cd 5 + SSP 100	456	479	439	458.0
A_1B_2	Cd 5 + SSP 150	512	442	474	476.0
A_1B_3	Cd 5 + SSP 200	486	458	523	489.0
A_2B_0	Cd 10 + SSP 0	314	336	364	338.0
A_2B_1	Cd 10 + SSP 100	406	364	382	384.0
A_2B_2	Cd 10 + SSP 150	396	373	425	398.0
A_2B_3	Cd 10 + SSP 200	448	408	425	427.0
A_3B_0	Cd 15 + SSP 0	322	304	346	324.0
A_3B_1	Cd 15 + SSP 100	342	371	403	372.0
A_3B_2	Cd 15 + SSP 150	389	363	421	391.0
A_3B_3	Cd 15 + SSP 200	439	414	395	416.0

S.E. = 19.40 C.D. = 39.61

B. Effect of Cd × SSP interaction on the uptake of Cd in shoot and root of Carrot

The data (Fig.-1& 2) indicated that the effect of Cd, SSP and Cd × SSP interaction were observed significant. Uptake of Cd in shoot and root of plants significantly increased and indicated greater relative uptake of Cd from control to Cd added plots. Application of 15 mg kg^{-1} Cd increased maximum uptake of Cd in shoot and root of Carrot by 1.80 and 2.56 mg kg^{-1}, respectively (Fig.-1& 2). Application of Cd 15 mg kg^{-1} + SSP 200 kg ha^{-1} decreased the uptake of Cd 0.88 mg kg^{-1} and 1.08 mg kg^{-1} in shoot and root of Carrot compared to non-amended plot, respectively. Added single doses of SSP 200 kg ha^{-1} decreases maximum uptake of Cd in shoot and root of Carrot by 0.03 and 0.05 mg kg^{-1} compared to control plots, respectively (Chen and Zhu, 2004; Biling et al., 2008; Mani et al., 2014a). Park et al., 2011; Tanq et al., 2011; Putwattana et al., 2015; Osborne et al., 2015 reported also almost similar findings. The uptake of metals from the soil to plant depends on different factors such as their soluble salt content in it, soil pH, plant growth stage types of species, fertilizer and soil (Sharma et al., 2006; Ismail et al., 2005).

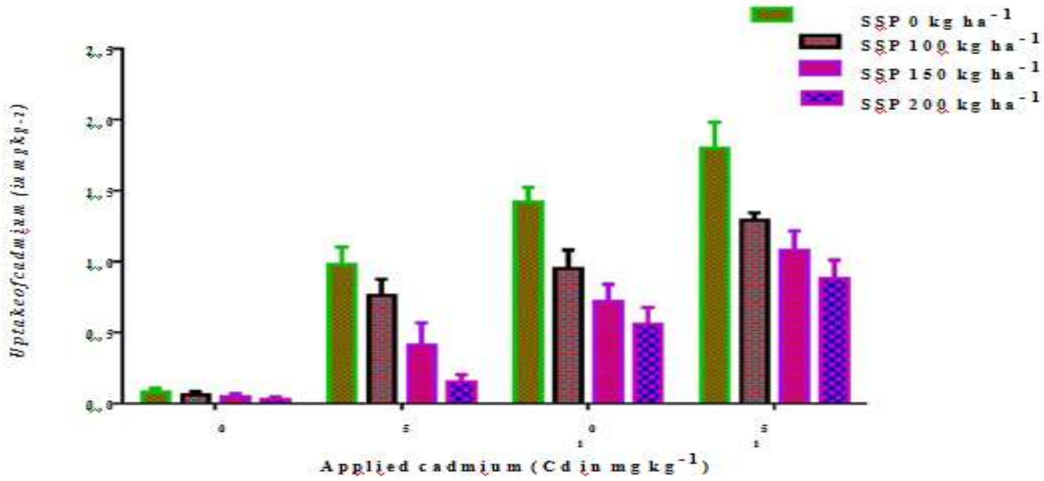

Fig. 1: Effect of Cd × SSP interaction on the uptake of Cd in shoot of Carrot (mg kg^{-1})

The addition of SSP 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 (Biling et al., 2008). Chen et al. (1997) 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.

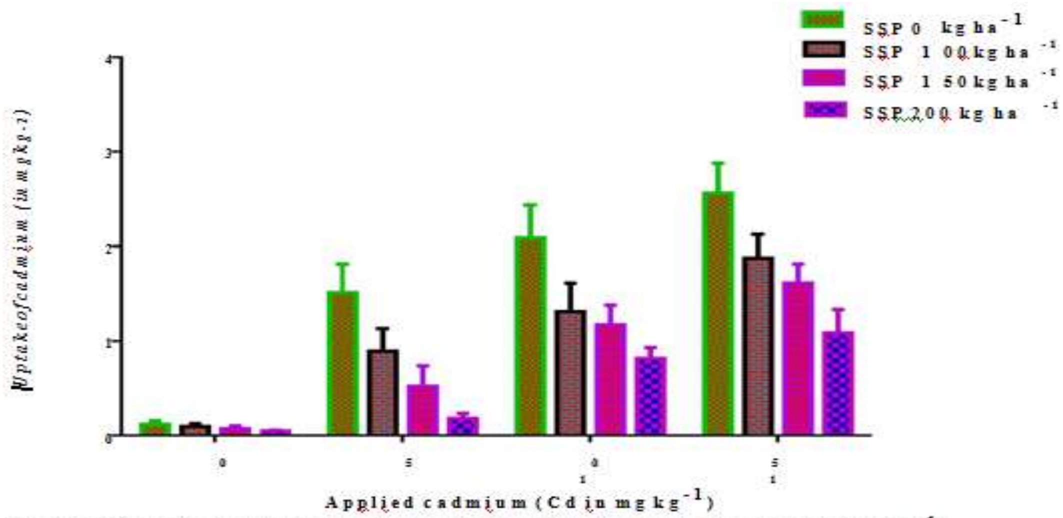

Fig. 2: Effect of Cd × SSP interaction on the uptake of Cd in root of Carrot (mg kg^{-1})

C. *Effect of Cd × SSP interaction on Bioaccumulation factor of Cd in Amaranth and Carrot*

Addition of SSP decreases the bioaccumulation factor (BF) of cadmium in Carrot (Fig.-3). Bioaccumulation factor of Cd in Carrot greater relative from control to Cd added plots. Application of Cd 15 mg kg^{-1} + SSP 200 kg ha^{-1} decreased bioaccumulation factor (BFs) of Cd 0.058 in Carrot compared to non-amended plot, respectively. Bioaccumulation factor of Cd increased maximum by Carrot 0.50 in control plot, respectively (Fig.-3). Added single doses of SSP 200 kg ha^{-1} decrease the BFs of Cd in Carrot by 0.19 compared to control plots, respectively. Almost similar findings also reported by Mani et al., 2015a; 2015b; Sun et al., 2011; Fuksova et al., 2009. Fuksova et al. (2009) observed BFs for Cd in *Salix* (1.01) and *Salix* plus (0.492) at a highly contaminated soil and BFs in *Thlaspi* (49.7), *Thlaspi* plus (43.5), *Salix* (7.53) and *Salix* plus (6.28) at a moderately contaminated soil, as compared to the observed BF in Carrot for Cd under the non-amended plots.

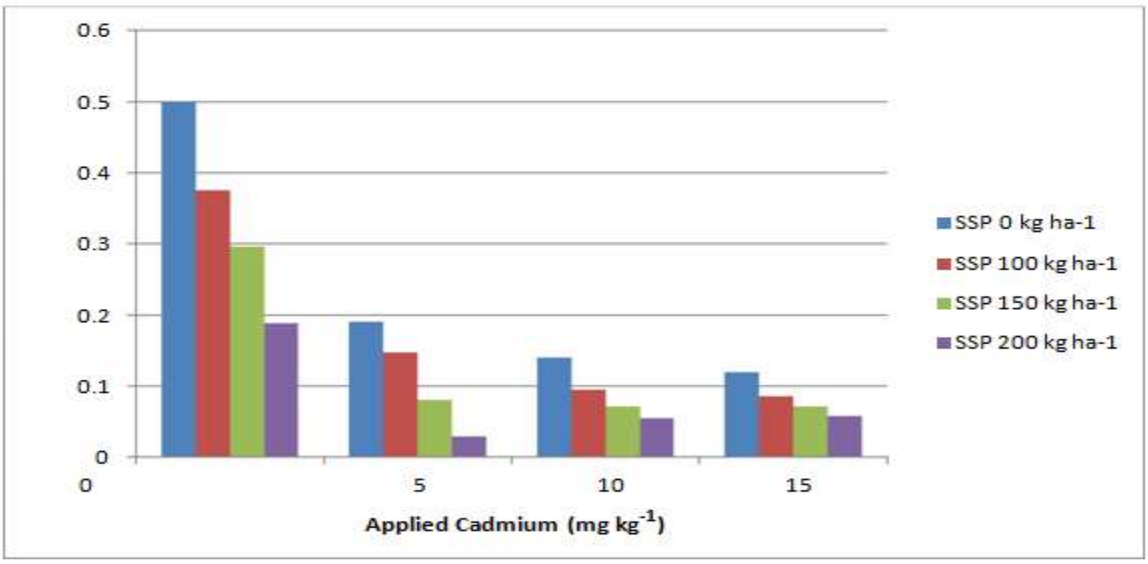

Fig. -3. Effect of Cd × SSP interaction on Bioaccumulation factor of Cd in Carrot

IV. CONCLUSION

Single super phosphate treated plots registered the highest dry biomass yield of Carrot by 26.50%. Application of SSP @ 200 kg ha^{-1} was found most effective in boosting the dry biomass content of crop. The application of 15 mg kg^{-1} Cd maximum reduces dry biomass of Carrot by 17.70% compared to control and registered the highest accumulation of Cd in shoot and root of Carrot by 1.80 and 2.56 mg kg^{-1}, respectively. Application of Cd 10 mg kg^{-1} + SSP 200 kg ha^{-1} decreased bioaccumulation factor (BFs) of Cd 0.055 in Carrot compared to non-amended plot. The reduced uptake of Cd was observed in SSP treated plots. An ameliorative effect of SSP was observed in Cd-contaminated soil. The results of presented study showed that SSP can effectively immobilize Cd in the soil. Single super phosphate has potential to reduce Cd uptake in both shoot and root of the Carrot plants.

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 Carrot or other vegetable crops in metals-contaminated areas and evaluate their growth and uptake of heavy metals in different edible parts of plants.

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