International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 10, No. 3, p. 132-142, 2017

INNSPUB

RESEARCH PAPER OPEN ACCESS

Salinity in soil increased cadmium uptake and accumulation potential of two terrestrial plants

Ayaz Ahmad*[1], Fazal Hadi[2], Habib Ahmad[3], Amin Ullah Jan[4], Khaista Rahman[1], Siraj Ahmad[5]

[1]*Department of Botany, Swat College of Science and Technology Swat, Khyber-Pakhtunkhwa, Pakistan*
[2]*Department of Biotechnology, University of Malakand, Chakdara, Dir Lower, Khyber Pakhtunkhwa, Pakistan*
[3]*Islamia College University Peshawar, Khyber Pakhtunkhwa, Pakistan*
[4]*Department of Biotechnology, Faculty of Science, Shaheed Benazir Bhutto University Sheringal Dir Upper, Khyber-Pakhtunkhwa, Pakistan*
[5]*Department of Botany, Govt. Post Graduate Jahanzeb College Swat, Pakistan*

Key words: Salinity, Cadmium, Soil, phytoremediation.

http://dx.doi.org/10.12692/ijb/10.3.132-142 Article published on March 17, 2017

Abstract

Cadmium (Cd) is a toxic heavy metal and its coexistence with high salt (NaCl) concentrations in soil not only reduce crops yield but also compromise the quality of food. Present study was carried out to investigate the effect of salinity in soil on Cd uptake and accumulation in two terrestrial plants. The effect of Cd and salt on plants growth and biomass were also studied two plants (*Ricinus communis* and *Sarcococca saligna*) were grown in pots containing different combinations of salt NaCl (1000, 3000 and 6000 ppm) with Cd metal (50, 100 and 150 ppm). Four controls were used; one without Cd (C) and NaCl while other three having different concentrations of Cd (C1=50 ppm, C2=100ppm and C3= 150ppm). Decrease in plants growth and biomass was observed under different concentrations of Cd in soil. Application of salt further decreased the biomass and growth of the plants. Combination of 6000 ppm NaCl and 150 ppm Cd in soil demonstrated highest significant Cd accumulation in the plants. *Ricinus communis* showed high Cd bio-concentration value (more than one) while bio-concentration value for other plant was less than one. It was also found that Cd accumulation in *Ricinus communis* plants was higher than the other plant. Salt of NaCl increased Cd uptake and accumulation in different parts of the plants. *Ricinus communis* demonstrated Cd hyper-accumulation potential. Edible crops should not be grown on soil polluted with NaCl and Cd to avoid entrance of the toxic metal into the food chain.

* **Corresponding Author:** Ayaz Ahmad ✉ qariayaz@gmail.com

Introduction

Saline soil has always been a problem for sustainable agriculture and environment. About 953 million hectors of total world's land is salt-affected that accounts for about 20% of the total agricultural land and 7% of the entire earth land (Sairam and Tyagi, 2004). Semiarid regions of the world are mostly exposed to the salinity problem due to low rainfall and high evaporative rate, which contribute towards increased salinization of soil (Viegas *et al*., 2001).

Presence of toxic heavy metals in saline soil makes the problem even worse. Cadmium (Cd) a toxic heavy metal and its coexistence in soil with NaCl salt has been reported in many literatures (McLaughlin *et al*. 1994). Cadmium (Cd) is easily absorb and accumulate by plants due to its strong bio-accumulative capacity (Hadi *et al*., 2014). Production of reactive oxygen species (ROS) under Cd stress damage cellular structures, which cause reduction in crops yield while Cd accumulation in edible parts of plants compromise the quality of food (Shafi *et al*., 2011).Consumption of contaminated food by humans result in serious health problems and even death (Saberi and Shahriari, 2011). Cadmium has been reported as a potential carcinogen and can cause damage of liver and kidneys (Ali and Hadi, 2015).

Due to the ever increasing demand for food, it is necessary to brought saline soil under cultivation but the presence of toxic metals in these soils compromise the food quality. Removal of toxic heavy metals from such soils require an effective and affordable remediation technology. Phytoextraction is one of the promising and environment friendly technology used for the safe restoration of toxic metals polluted soil (Ali and Hadi2015). Plants have the natural ability to absorb almost any substance present in solution form within soil and this potential of green plants can be used for the safe restoration of toxic metals polluted soils.

In the present research two plant species (*Ricinus communis* and *Sarcococca saligna*) were tested for their cadmium phytoextraction potential in different saline soils.

Materials and methods

Soil preparation and plants Material

Fertile soil was obtained from agricultural fields near the University of Malakand and grinded into fine powdered form after drying in sunlight and poured into clay pots (3 kg soil/pot). Water holding capacity (250 mL water/kg soil ±4), electrical conductivity (814 µs ± 7) and pH (6.7 ± 2) of the soil was measured. Two different plants (*Ricinus communis* and *Sarcococca saligna*) were used during the experiment. Seeds of the plants (obtained from the herbarium of University of Malakand, Pakistan) were sown in soil beds in glass house. After germination uniform size plantlets (2 cm roots and 3 cm shoot) were selected for the experiment.

Treatments used during the experiment

Soil in pots was polluted with Cd in the form of Cadmium acetate dihydrate [Cd $(CH_3COO)_2$. $2H_2O$] solution at three different concentrations (50, 100 and 150 ppm Cd). Sodium salt (NaCl) was added to soil in pots in different concentrations (1000, 3000 and 6000 ppm) in solution form. Three replicate pots were used for each treatment and control and placed in completely randomized design (CRD). The experiment was conducted under natural light/dark conditions with temperature 30/25^{o}C. The following treatments and control (Table 1) were used during the experiment.

Plants were harvested after two months treatments. After harvesting, the root, stem and leaf length was measured using centimetre ruler.

Then the plants were separated into three parts i.e. roots, stem and leaves. The fresh biomass of the different parts was measured for each plant using analytical balance. Each part was packed in labeled paper envelope. The samples were dried at 80 ^{o}C for 48 hrs in oven. The dried samples were crushed into powdered form using mortar and pestle, and each sample was kept in small polythene bags for further use.

Acid Digestion and Cd Analysis in Plants Tissues

Dried samples were digested and cadmium content in samples was measured by method of Allen (1974) with slight modification. From each sample 0.25 g was taken in separate conical flask and a mixture of acids (Nitric acid and Sulfuric acid in ratio of 5: 1) was added to it and heated until completely digested. Solution is cooled, filtered into plastic bottles and final volume of each filtrate was raised up to 50 ml with distilled water. Each liquid sample was then analyzed for Cd concentration using atomic absorption spectrophotometer.

Statistical analysis

The data was analyzed using SPSS-16 and MS-excel (2010). The data was subjected to ANOVA and the mean values were compared by using Tukey's Honestly Significant Difference (HSD) test, at $P < 0.05$.

Results

Effect of Cd on Growth, Biomass and water content of Plants

The effect of different treatments on plants growth is shown in Figure 1.

The root, stem and leaf length of *Ricinus* and *Sarcococca* plants are given in Tables 2 (A, B) respectively. All the plants showed significant decrease in growth, biomass and total water content under different Cd concentrations (50, 100 and 150 ppm).

Table 1. Different Treatments of Cd and NaCl used during experiments. C is compared with all treatments to find out the effect of Cd alone and in combinations with salt (NaCl) on plant growth while C1, C2 and C3 are compared with all other treatments for NaCl effect on Cd phyto-accumulation.

Treatments	Denoted	Treatments	Denoted
Growth media Soil only	C	100 ppm Cd + 1000 ppm NaCl	T4
50 ppm Cd	C1	100 ppm Cd + 3000 ppm NaCl	T5
100 ppm Cd	C2	100 ppm Cd + 6000 ppm NaCl	T6
150 ppm Cd	C3	150 ppm Cd + 1000 ppm NaCl	T7
50 ppm Cd +1000 ppm NaCl	T1	150 ppm Cd + 3000 ppm NaCl	T8
50 ppm Cd + 3000 ppm NaCl	T2	150 ppm Cd + 6000 ppm NaCl	T9
50 ppm Cd + 6000 ppm NaCl	T3		

Harvesting of Plants and Measurement of Different Parameters.

This decrease was highly significant at the highest concentration of Cd (150 ppm) when the control without Cd (C) was compared with Cd treated plants (C1, C2 and C3) as shown in Tables 2 (A,B) respectively for *Ricinus* and *Sarcococca* plants.

In exception, the decrease in stem and leaf length of *Ricinus* plant at lower concentrations of Cd was not statistically significant as compared to control C (Table 2A). Similarly, the lowest concentration of Cd (50 ppm) shows non-significant decrease in all the above growth parameters as compared to the control C (Table 2B).

The results showed a gradual decline in growth parameters in all the plants with increasing Cd concentration.

Combine Effect of Cd and Salt (NaCl) on Plant Growth and biomass

The higher concentrations (3000 and 6000 ppm) of NaCl salt in combination with Cd significantly decreased the growth, biomass and total water content of both *Ricinus* (Table 2A) and *Sarcococca* (Table 2B) plants when C1 (50 ppm Cd in Soil) was compared with T2 (50 ppm Cd + 3000 ppm NaCl in Soil) and T3 (50 ppm Cd + 6000 ppm NaCl in Soil).

Similarly, when C2 (100 ppm Cd in Soil) was compared with T5 (100 ppm Cd + 3000 ppm NaCl in Soil) and T6 (100 ppm Cd + 6000 ppm NaCl in Soil), and C3 (150 ppm Cd in Soil) when compared with T8 (150 ppm Cd + 3000 ppm NaCl in Soil) and T9 (150 ppm Cd + 6000 ppm NaCl in Soil) given in Table 2 (A, B).

The lower concentration of NaCl (1000 ppm NaCl in Soil) in combination with Cd (T1, T4 and T7) showed no significant difference in all the growth parameters when compared C1, C2 and C3 respectively.

The highest significant decrease in all the above growth parameters for *Ricinus* plant was recorded for the treatment T9 (150 ppm Cd + 6000 ppm NaCl) as compared to control C.

Table 2A. Effect of different treatments on *Ricinus communis* plant. C (Soil without Cd and NaCl addition), C1, C2, C3 (50, 100, 150 ppm Cd in Soil), T1, T2, T3 (1000, 3000, 6000 ppm NaCl + 50 ppm Cd with each NaCl concentration), T4, T5, T6 (1000, 3000, 6000 ppm NaCl + 100 ppm Cd), T7, T8, T9 (1000, 3000, 6000 ppm NaCl + 150 ppm Cd). ±SD denote Standard deviation and different letters show the significant difference among different treatment for a specific parameter.

Treatments	Length (cm) ± SD			Fresh biomass (g) ± SD			Dry biomass (g) ± SD			Total water contents (g) ± SD		
	Root	Stem	Leaves	Root	Stem	Leaves	Root	Stem	Leaves	Root	Stem	Leaves
C	18.50 ± 0.50 ^{a}	28.00 ± 1.00 ^{a}	19.50 ± 0.50 ^{a}	3.22 ± 0.13 ^{a}	4.88 ± 0.24 ^{a}	3.4 ± 0.13 ^{a}	1.29 ± 0.05 ^{a}	1.95 ± 0.10 ^{a}	1.36 ± 0.05 ^{a}	1.93 ± 0.08 ^{a}	2.93 ± 0.14 ^{a}	2.04 ± 0.08 ^{a}
C1	15.50 ± 0.50 ^{b}	23.50 ± 0.50 ^{ab}	16.50 ± 0.50 ^{ab}	2.37 ± 0.08 ^{b}	3.61 ± 0.32 ^{bc}	2.52 ± 0.09 ^{b}	0.95 ± 0.03 ^{b}	1.44 ± 0.13 ^{b}	1.01 ± 0.04 ^{b}	1.42 ± 0.05 ^{b}	2.16 ± 0.19 ^{b}	1.51 ± 0.06 ^{b}
C2	13.50 ± 0.50 ^{bc}	22.50 ± 0.50 ^{abc}	14.00 ± 1.00 ^{bc}	1.76 ± 0.24 ^{cde}	2.92 ± 0.22 ^{bc}	1.81 ± 0.05 ^{cd}	0.71 ± 0.09 ^{c}	1.17 ± 0.09 ^{bc}	0.72 ± 0.02 ^{cd}	1.06 ± 0.14 ^{c}	1.75 ± 0.13 ^{bc}	1.09 ± 0.03^{cd}
C3	12.00 ± 1.00 ^{c}	18.00 ± 6.00 ^{bcd}	13.50 ± 0.50 ^{bc}	1.66 ± 0.13 ^{cde}	2.48 ± 0.81 ^{cde}	1.86 ± 0.06 ^{bc}	0.66 ± 0.05 ^{cd}	0.99 ± 0.33 ^{cde}	0.75 ± 0.02 ^{bc}	0.99 ± 0.08 ^{cd}	1.49 ± 0.49 ^{cde}	1.12 ± 0.03 ^{bc}
T1	14.00 ± 2.00 ^{bc}	19.50 ± 0.50 ^{bc}	15.50 ± 0.50 ^{bc}	1.83 ± 0.05 ^{cde}	2.59 ± 0.24 ^{cde}	2.07 ± 0.31 ^{bc}	0.73 ± 0.02 ^{c}	1.04 ± 0.10 ^{cd}	0.83 ± 0.12 ^{bc}	1.1 ± 0.03 ^{c}	1.55 ± 0.14 ^{cd}	1.24 ± 0.19 ^{bc}
T2	12.50 ± 0.50 ^{c}	16.00 ± 0.02 ^{cde}	10.00 ± 1.00 ^{d}	1.47 ± 0.24 ^{cde}	1.87 ± 0.23 ^{def}	1.16 ± 0.03 ^{de}	0.59 ± 0.10 ^{cde}	0.75 ± 0.09 ^{def}	0.46 ± 0.01 ^{de}	0.88 ± 0.14 ^{cde}	1.12 ± 0.14 ^{def}	0.69 ± 0.02 ^{de}
T3	7.50 ± 0.50 ^{d}	9.00 ± 2.00 ^{f}	4.00 ± 1.00 ^{ef}	1.1 ± 0.01 ^{ef}	1.30 ± 0.20 ^{f}	0.6 ± 0.19 ^{e}	0.44 ± 0.09 ^{ef}	0.52 ± 0.08 ^{f}	0.24 ± 0.08 ^{e}	0.66 ± 0.09 ^{ef}	0.78 ± 0.12 ^{f}	0.36 ± 0.11 ^{e}
T4	13.50 ± 0.50 ^{bc}	17.50 ± 0.50 ^{bcd}	15.00 ± 1.00 ^{bc}	1.45 ± 0.21 ^{cde}	1.90 ± 0.39 ^{def}	1.64 ± 0.4 ^{cd}	0.58 ± 0.08 ^{cde}	0.76 ± 0.16 ^{def}	0.66 ± 0.16 ^{cd}	0.87 ± 0.12 ^{cde}	1.14 ± 0.24 ^{def}	0.99 ± 0.24 ^{cd}
T5	7.00 ± 0.00 ^{de}	10.00 ± 1.00 ^{ef}	5.50 ± 0.50 ^{e}	0.93 ± 0.02 ^{f}	1.33 ± 0.10 ^{f}	0.74 ± 0.08 ^{e}	0.37 ± 0.01 ^{f}	0.53 ± 0.04 ^{f}	0.29 ± 0.03 ^{e}	0.56 ± 0.01 ^{f}	0.8 ± 0.06 ^{f}	0.44 ± 0.05 ^{e}
T6	4.50 ± 0.50 ^{ef}	9.00 ± 0.90 ^{f}	3.50 ± 0.50 ^{ef}	0.79 ± 0.09 ^{f}	1.59 ± 0.90 ^{ef}	0.62 ± 0.09^{e}	0.32 ± 0.04 ^{f}	0.64 ± 0.09 ^{ef}	0.25 ± 0.04 ^{e}	0.48 ± 0.05 ^{f}	0.95 ± 0.09 ^{ef}	0.37 ± 0.05 ^{e}
T7	11.50 ± 1.50 ^{c}	12.50 ± 2.50 ^{def}	12.50 ± 0.50 ^{cd}	1.25 ± 0.27 ^{cdef}	1.32 ± 0.20 ^{f}	1.43 ± 0.53 ^{cd}	0.50 ± 0.11 ^{def}	0.53 ± 0.08 ^{f}	0.57 ± 0.21 ^{cd}	0.75 ± 0.16 ^{def}	0.79 ± 0.12 ^{f}	0.86 ± 0.32 ^{cd}
T8	4.50 ± 0.50 ^{ef}	9.00 ± 4.00 ^{f}	5.00 ± 3.00 ^{ef}	0.83 ± 0.26 ^{f}	1.43 ± 0.07 ^{f}	0.73 ± 0.19 ^{e}	0.33 ± 0.10 ^{f}	0.57 ± 0.03 ^{f}	0.29 ± 0.08 ^{e}	0.51 ± 0.15 ^{f}	0.86 ± 0.04 ^{f}	0.44 ± 0.11 ^{e}
T9	3.50 ± 0.50 ^{ef}	7.00 ± 1.00 ^{f}	2.00 ± 0.07 ^{f}	0.84 ± 0.02 ^{f}	1.68 ± 0.04 ^{ef}	0.49 ± 0.06 ^{e}	0.34 ± 0.01 ^{f}	0.67 ± 0.02 ^{ef}	0.19 ± 0.02 ^{e}	0.50 ± 0.01 ^{f}	1.01 ± 0.02 ^{ef}	0.29 ± 0.04 ^{e}

Table 2B. Effect of different treatments on *Sarcococca* plant. C (Soil without Cd and NaCl addition), C1, C2, C3 (50, 100, 150 ppm Cd in Soil), T1, T2, T3 (1000, 3000, 6000 ppm NaCl + 50 ppm Cd with each NaCl concentration), T4, T5, T6 (1000, 3000, 6000 ppm NaCl + 100 ppm Cd), T7, T8, T9 (1000, 3000, 6000 ppm NaCl + 150 ppm Cd). ±SD denote Standard deviation and different letters show the significant difference among different treatments for a specific parameter.

Treatments	Length cm			Fresh biomass g			Dry biomass g			Total water contents g		
	Root	stem	Leaves	root	stem	leaves	root	Stem	leaves	root	stem	leaves
C	26.00 ± 1.00 ^{a}	34.00 ± 1.00 ^{a}	8.50 ± 0.50 ^{a}	2.12 ± 0.26 ^{a}	2.77 ± 0.38 ^{a}	0.70 ± 0.16 ^{a}	0.85 ± 0.10 ^{a}	1.11 ± 0.15 ^{a}	0.28 ± 0.06 ^{a}	1.27 ± 0.16 ^{a}	1.67 ± 0.22 ^{a}	0.42 ± 0.09 ^{a}
C1	18.50 ± 0.50 ^{cd}	29.00 ± 1.00 ^{ab}	5.5 ± 0.50 ^{b}	1.25 ± 0.08 ^{bcd}	1.97 ± 0.25 ^{b}	0.38 ±0.07 ^{b}	0.50 ± 0.032 ^{bcd}	0.78 ± 0.09 ^{b}	0.15 ± 0.02 ^{b}	0.75 ± 0.05 ^{bcd}	1.18 ± 0.15 ^{b}	0.23 ± 0.04 ^{b}
C2	20.00 ± 1.00 ^{bc}	26.50 ± 2.50 ^{bc}	3.50 ± 0.50 ^{cd}	1.34 ± 0.35 ^{bc}	1.81 ± 0.23 ^{b}	0.24 ± 0.02 ^{bc}	0.54 ±0.142 ^{bc}	0.72 ± 0.09 ^{b}	0.09 ± 0.01 ^{bc}	0.80 ± 0.21 ^{bc}	1.09 ± 0.13 ^{b}	0.14 ± 0.01^{bc}
C3	22.00 ± 1.00 ^{b}	23.00 ± 1.00 ^{cd}	2.50 ± 0.50 ^{de}	1.52 ± 0.08 ^{b}	1.60 ± 0.23 ^{b}	0.17 ± 0.02 ^{bc}	0.61 ±0.03 ^{b}	0.64 ± 0.09 ^{b}	0.06 ± 0.01 ^{bc}	0.91 ± 0.05 ^{b}	0.96 ± 0.13 ^{b}	0.10 ± 0.01 ^{bc}

T1	17.00 ± 1.00 bc	28.50 ± 1.50 abc	3.50 ± 0.50 cd	1.26 ± 0.29 bcd	1.89 ± 0.44 b	0.24 ± 0.07 bc	0.51 ±0.11 bcd	0.75 ± 0.17 b	0.09 ± 0.02 bc	0.75 ± 0.17 bcd	1.14 ± 0.26 b	0.14 ± 0.04 bc
T2	13.50 ± 1.50 cd	20.00 ± 4.00 de	3.49 ± 0.51cd	1.03 ± 0.01 bcde	1.58 ± 0.46 b	0.26 ± 0.06 bc	0.42 ± 0.01 bcde	0.63 ± 0.18 b	0.11 ± 0.02 bc	0.62 ± 0.01 bcde	0.95 ± 0.27 b	0.17 ± 0.04 bc
T3	12.50 ± 2.50 de	18.00 ± 2.00 de	3.00 ± 1.00 cde	0.92 ± 0.23 cde	1.46 ± 0.23 b	0.21 ± 0.06 bc	0.37 ± 0.09 cde	0.58 ± 0.09 b	0.08 ± 0.02 bc	0.55 ± 0.14 cde	0.88 ± 0.13 b	0.13 ± 0.04 bc
T4	17.50 ± 0.50 d	23.00 ± 1.00 cd	4.00 ± 1.00 bcd	1.21 ± 0.04 bcd	1.60 ± 0.17 b	0.28 ± 0.09 bc	0.49 ± 0.01 bcd	0.64 ± 0.06 b	0.10 ± 0.03 bc	0.72 ± 0.03 bcd	0.96 ± 0.10 b	0.17 ± 0.05 bc
T5	9.00 ± 1.00 ef	17.00 ± 2.00 e	3.15 ± 1.00 cde	0.83 ± 0.00 cde	1.57 ± 0.02 b	0.29 ± 0.12 bc	0.33 ± 0.01 cde	0.63 ± 0.01 b	0.10 ± 0.04 bc	0.50 ± 0.01 cde	0.94 ± 0.01 b	0.17 ± 0.07 bc
T6	9.30 ± 2.00 ef	16.00 ± 1.00 e	2.50 ± 0.50 de	0.81 ± 0.11 de	1.46 ± 0.04 b	0.23 ± 0.03 bc	0.32 ± 0.04 de	0.58 ± 0.01 b	0.09 ± 0.01 bc	0.48 ± 0.07 de	0.88 ± 0.02 b	0.14 ± 0.02 bc
T7	19.00 ± 1.00 bc	25.00 ± 2.00 bcd	4.50 ±0.50 bc	1.29 ± 0.14 bcd	1.69 ± 0.03 b	0.30 ± 0.02 bc	0.52 ± 0.05 bcd	0.67 ± 0.01 b	0.12 ± 0.01 bc	0.78 ± 0.09 bcd	1.02 ± 0.01 b	0.18 ± 0.01 bc
T8	6.50 ± 0.50 f	15.50 ± 1.50 e	3.50 ± 0.50 cd	0.58 ± 0.03 e	1.40 ± 0.17 b	0.31 ± 0.04 bc	0.23 ± 0.01 e	0.56 ± 0.06 b	0.16 ± 0.01 bc	0.35 ± 0.02 e	0.84 ± 0.10 b	0.19 ± 0.02 bc
T9	5.50 ± 0.50 f	12.00 ± 1.00 e	1.50 ± 0.50 e	0.55 ± 0.10 e	1.49 ± 0.04 b	0.15 ± 0.06 c	0.22 ± 0.04 e	0.59 ± 0.01 b	0.06 ± 0.02 c	0.33 ± 0.06 e	0.89 ± 0.02 b	0.09 ± 0.04 c

All concentrations (1000, 3000 and 6000 ppm) of NaCl salt in combination with 100 ppm Cd significantly decreased the leaf length of *Sarcococca* plant. The plant stem length showed significant decrease in combination treatments containing higher concentration (3000 and 6000 ppm) of NaCl salt as T2, T3, T5, T6, T8, and T9 when compared with C1, C2 and C3 respectively (Table 2).

Root length of plant was significantly decreased in combination (Cd + NaCl) treatment T3 compared to C1, and T5, T6 when compared with C2 and treatments T8 and T9 when compared to C3 (Table 2D). The decrease in biomass (fresh and dry) and total water content was almost non-significant but this decrease was significant only for treatments T6 (compared to C2), T8 and T9 (compared to C3) as shown in Table 2(D).

Table 3A. Cadmium concentration and accumulation by various parts of *Ricinus communis* grown in soil having different concentrations of NaCl salt and cadmium. C1, C2, C3 (50, 100, 150 ppm Cd in Soil), T1, T2, T3 (1000, 3000, 6000 ppm NaCl + 50 ppm Cd with each NaCl concentration), T4, T5, T6 (1000, 3000, 6000 ppm NaCl + 100 ppm Cd), T7, T8, T9 (1000, 3000, 6000 ppm NaCl + 150 ppm Cd). ±SD denote Standard deviation and different letters show the significant difference among different treatments for a specific parameter.

Treatment	Cd concentration (ppm)			Cd (mg/DBM)			Entire plant Cd accumulation (mg/DBM)	Cd accumulation %			Translocation Factor (TF)		Bio- concentration Factor (BCF)
	Root	Stem	Leaves	Root	stem	Leaves		Root	Stem	Leaf	Root-stem	Root-leaves	
C1	63 ± 2.24 k	38.4 ± 1.24 f	54.2 ± 1.2 i	0.06 ± 0.0036 d	0.055 ± 0.0059 ab	0.054 ± 0.0028 ab	0.17 ± 0.0123 bcde	35.18 ± 0.55	32.57 ± 1.19	32.23 ± 0.7	0.61	0.86	1.04
C2	101.8 ± 0.66 h	77.8 ± 1.74 de	72.6 ± 2.62 g	0.07 ± 0.0098 cd	0.091 ± 0.0079 ab	0.052 ± 0.0028 ab	0.216 ± 0.0201 abc	33.26 ± 1.52	42.26 ± 0.29	24.47 ± 1.22	0.76	0.71	0.86
C3	112± 2.08 g	93.8 ± 2.24 cde	79.6 ± 1.94 f	0.07 ± 0.0065 bcd	0.093 ± 0.0313 ab	0.059± 0.0028 a	0.227 ± 0.0404 ab	33.09 ± 3.15	40.31 ± 6.82	26.59 ± 3.67	0.84	0.71	0.64
T1	76.8 ± 2.54 j	65 ± 0.5 ef	50.2 ± 1.5 i	0.06 ± 0.0017 d	0.067 ± 0.0064 ab	0.041 ± 0.0068 abc	0.165 ± 0.013 bcde	34.20 ± 2.95	40.7 ± 0.89	25.09 ± 2.2	0.85	0.65	1.26
T2	84 ± 0.6 i	93.6 ± 2.22 cde	75 ± 1.96 fg	0.05 ± 0.0082 d	0.07 ± 0.0095 ab	0.034 ± 0.0015 bc	0.154 ± 0.0191 cde	31.91 ± 1.42	45.44 ± 0.59	22.64 ± 1.96	1.11	0.89	1.76
T3	94 ±	111.8 ±	108.4 ±	0.04 ±	0.058 ±	0.025 ±	0.126 ±	32.89 ±	46.39 ±	20.71 ±	1.19	1.15	2.17

	1.62 ^{f}	0.78 ^{abc}	1.52 ^{d}	0.0006 ^{d}	0.009 ^{ab}	0.008 ^{c}	0.0017 ^{e}	0.26	6.81	6.6			
T4	116 ± 1.44 ^{f}	88.8 ± 1.32 ^{cde}	67 ± 2.28 ^{h}	0.07 ± 0.01 ^{d}	0.068 ± 0.0144 ^{ab}	0.044 ± 0.0113 ^{abc}	0.179 ± 0.0357 ^{bcde}	37.87 ± 2.06	37.69 ± 0.53	24.43 ± 1.56	0.77	0.58	0.88
T5	131 ± 0.7 ^{e}	108.8 ± 0.94 ^{abcd}	102 ± 0.62 ^{e}	0.05 ± 0.0012 ^{d}	0.058 ± 0.0043 ^{ab}	0.03 ± 0.0035 ^{c}	0.137 ± 0.0009 ^{de}	35.75 ± 0.78	42.32 ± 3.25	21.91 ± 2.47	0.83	0.78	1.22
T6	154 ± 1.82 ^{d}	114 ± 37.2 ^{abc}	118 ± 0.78 ^{c}	0.05 ± 0.005 ^{d}	0.072 ± 0.0236 ^{ab}	0.029 ± 0.0043 ^{c}	0.15 ± 0.0238 ^{cde}	33.20 ± 7.79	47.25 ± 8.37	19.53 ± 2.77	0.74	0.77	1.28
T7	220 ± 0.86 ^{c}	102.2 ± 1 ^{bcd}	70.6 ± 0.44 ^{gh}	0.11 ± 0.023 ^{abc}	0.054 ± 0.0077 ^{b}	0.040 ± 0.0149 ^{abc}	0.204 ± 0.0461 ^{abcd}	53.80 ± 0.69	26.79 ± 2.34	19.39 ± 3.02	0.46	0.32	0.80
T8	332 ± 1.02 ^{b}	133.8 ± 1.24 ^{ab}	135.8 ± 2.78 ^{b}	0.11 ± 0.034 ^{ab}	0.077 ± 0.0033 ^{ab}	0.039 ± 0.0098 ^{abc}	0.227 ± 0.0213 ^{ab}	48.09 ± 10.6	34.01 ± 4.66	17.89 ± 5.99	0.40	0.41	1.36
T9	387 ± 1.54 ^{a}	140 ± 0.8 ^{a}	156 ± 2.4 ^{a}	0.13 ± 0.003 ^{a}	0.094 ± 0.0025 ^{a}	0.030 ± 0.0034 ^{c}	0.254 ± 0.0027 ^{a}	51.07 ± 0.83	36.95 ± 0.63	11.97 ± 1.45	0.36	0.40	1.41

Cadmium Concentration and Accumulation in Plants

Ricinus communis plant showed a significant increase in tissues (Root, Stem and Leaves) Cd concentration with increasing Cd concentration (50, 100 and 150 ppm) in soil, when compared C1, C2 and C3 in Table 3 (A). Similarly, the total Cd accumulation in different parts of the plant also increased as the Cd concentration in soil was increased, but this increase was statistically not significant.

Salt (NaCl) showed positive and significant effect on Cd concentration and accumulation in various parts of the plant (Table 3A). Increasing Cd and sodium salt concentration in the soil increased the Cd concentration in different parts of the plant and thus the highest significant Cd concentration (Root "387± 1.54 ppm", Stem "140 ± 0.8 ppm" and leaf "156 ± 2.4 ppm") was recorded for the treatment T9 (150 ppm Cd + 6000 ppm NaCl).

Table 3B. Cadmium concentration and accumulation by various parts of *Sarcococca* grown in soil having different concentration s of salt and cadmium.C1, C2, C3 (50, 100, 150 ppm Cd in Soil), T1, T2, T3 (1000, 3000, 6000 ppm NaCl + 50 ppm Cd with each NaCl concentration), T4, T5, T6 (1000, 3000, 6000 ppm NaCl + 100 ppm Cd), T7, T8, T9 (1000, 3000, 6000 ppm NaCl + 150 ppm Cd). ±SD denote Standard deviation and different letters show the significant difference among different treatments for a specific parameter.

Treatments	Cd conc. (ppm)			Cd (mg/DBM)			total plant Cd (mg/DBM)	Cd %			Translocation factor		bio-concentration factor
	Roots	Stem	Leaves	Roots	Stem	Leaves	R+S+L	Roots	Stem	Leaves	Root to stem	Root to leaves	
C1	21 ± 1.23 ^{d}	16.60 ± 1.56 ^{cd}	10.00 ± 2.00 ^{d}	0.0022 ± 0.0002 ^{f}	0.00139 ± 0.00024 ^{c}	0.00053 ± 0.0002 ^{de}	0.0041 ± 0.0006 ^{e}	54.30 ± 3.88	33.59 ±.40	12.10 ± 3.47	0.79	0.47	0.35
C2	22.8 ± 1.74 ^{d}	23.00 ± 2.22 ^{cd}	15.60 ± 3.00 ^{d}	0.0026 ± 0.0004 ^{f}	0.00267 ± 0.00037 ^{c}	0.0012 ± 0.0003 ^{de}	0.0071 ± 0.0010 ^{e}	40.20 ± 5.05	40.87 ± 0.36	18.95 ± 4.71	1.01	0.69	0.22
C3	31.6 ± 2.48 ^{cd}	34.00 ± 2.54 ^{c}	20.60 ± 1.00 ^{cd}	0.0054 ± 0.0006 ^{def}	0.00579 ± 0.00058 ^{c}	0.0022 ± 0.0001 ^{ede}	0.0131 ± 0.0012 ^{de}	37.40 ± 0.71	46.55 ± 0.86	16.02 ± 1.57	1.15	0.66	0.21
T1	22 ± 10.5 ^{d}	19.00 ± 1.98 ^{d}	13.60 ± 5.00 ^{d}	0.0025 ± 0.0033 ^{f}	0.00185 ± 0.00067 ^{c}	0.0009 ± 0.0011 ^{c}	0.0051 ± 0.0051 ^{e}	46.40 ± 10.6	34.83 ± 12.90	18.81 ± 2.33	0.87	0.64	0.40
T2	21.2 ±4.9 ^{d}	22.40 ± 3.50 ^{cd}	20.60 ± 0.5 ^{cd}	0.0023 ± 0.0011 ^{f}	0.00256 ± 0.00067 ^{c}	0.0021 ± 0.0001 ^{cde}	0.0071 ± 0.0017 ^{e}	32.80 ± 4.83	36.22 ± 0.85	30.96 ± 5.68	1.05	0.97	0.44
T3	26.8 ± 2.28 ^{cd}	29.60 ± 3.94 ^{cd}	23.60 ± 2.00 ^{c}	0.004 ± 0.0005 ^{ef}	0.00442 ± 0.00088 ^{c}	0.0022 ± 0.0005 ^{cd}	0.0111 ± 0.0018 ^{de}	31.90 ± 1.70	41.70 ± 3.17	26.38 ± 1.46	1.23	0.98	0.56
T4	28.8 ± 11.6 ^{cd}	27.00 ± 3.26 ^{cd}	20.40 ± 3.00 ^{cd}	0.0042 ± 0.0031 ^{def}	0.00365 ± 0.00097 ^{c}	0.0021 ±0.0007 ^{cde}	0.0112 ± 0.004 ^{de}	41.70 ± 14.20	37.4 0± 9.05	20.85 ± 5.18	0.95	0.70	0.27
T5	29.8 ± 3.9 ^{cd}	27.20 ± 0.82 ^{cd}	25.60 ± 4.00 ^{c}	0.0045 ±0.0011 ^{def}	0.00372 ± 0.00022 ^{c}	0.0033 ± 0.0008 ^{c}	0.0121 ± 0.0021 ^{de}	38.70 ± 2.19	32.57 ± 5.95	28.72 ± 3.76	0.92	0.86	0.28
T6	41.8 ± 4.52 ^{bc}	35.00 ± 2.52 ^{c}	27.00 ± 3.00 ^{c}	0.0087 ± 0.0013 ^{cd}	0.00665 ± 0.00069 ^{c}	0.0036 ± 0.0008 ^{c}	0.0191 ± 0.0027 ^{d}	47.60 ± 2.33	32.46 ± 1.95	19.97 ± 0.37	0.83	0.65	0.36

T7	39.2 ± 0.96 [bc]	63.20 ± 12.54 [b]	37.60 ± 0.7 [b]	0.0077 ± 0.0004 [cde]	0.02002 ± 0.00441 [b]	0.0071 ± 0.0001 [b]	0.0351 ± 0.0048 [c]	22.10 ± 9.85	57.55 ± 14.73	20.35 ± 4.88	1.61	0.96	0.34
T8	83.6 ± 3.14 [a]	76.40 ± 3.70 [a]	48.60 ± 3.00 [a]	0.0349 ± 0.0012 [b]	0.02919 ± 0.00234 [a]	0.0118 ± 0.0011 [a]	0.0761 ± 0.0045 [b]	46.00 ± 0.65	38.43 ± 0.80	15.55 ± 0.15	0.91	0.58	0.50
T9	89.2 ± 0.7 [a]	81.00 ± 0.52 [a]	52.20 ± 1.00 [a]	0.0398 ± 0.0006 [a]	0.03282 ± 0.0004 [a]	0.0136 ± 0.0007 [a]	0.0861 ± 0.0016 [a]	46.10 ± 0.24	38.05 ± 0.32	15.80 ± 0.56	0.91	0.59	0.54

The highest Cd accumulation (mg/DBM) in root (0.13 ± 0.003 mg/DBM), stem (0.094 ± 0.0025 mg/DBM) and entire plant (0.254 ± 0.0027 mg/DBM) was observed in treatment T9, while in leaves (0.030 ±0.0034 mg/DBM) it was observed inC3 (150 ppm Cd, without addition of NaCl salt in soil).

Increasing Cd concentration in soil increased the Cd accumulation percentage in stem while decreased this percentage in roots and leaves when compared C1, C2 with C3 (Table 3A).

The highest Cd percentage in roots (53.80 ± 0.69%) was recorded for treatment T7 (150 ppm Cd + 1000 ppm NaCl in Soil), in stem (47.25± 8.37%) for T6 (100 ppm Cd + 6000 ppm NaCl in Soil) and in leave (32.23 ± 0.7%) for C1 (50 ppm Cd in Soil). The treatment T3 (50 ppm Cd + 6000 ppm NaCl in Soil) showed the highest translocation factors (1.19 root-stem and 1.15 root- leaves) and bioaccumulation factor (2.17) as shown in Table 3(A).

Sarcococca plant showed the highest root, stem and leaves Cd concentration for the treatments T8 (150 ppm Cd + 3000 ppm NaCl in Soil) and T9 (150 ppm Cd + 6000 ppm NaCl in Soil) (Table 3B).

Increasing Cd concentration in soil increased Cd concentration in different parts of the plant. The highest entire plant Cd (0.0861 ±0.0016 mg/DBM) was observed in plants grown in soil containing the highest Cd and NaCl salt concentration T9 (150 ppm Cd + 6000 ppm NaCl in Soil) as shown in Table 9.

The highest Cd translocation factor (1.61 root to stem, 0.96 root to leaves) was recorded for the treatment T7 (150 ppm Cd + 1000 ppm NaCl in Soil) while the highest Cd bio-concentration factor (0.56) was observed for the treatment T3 (50 ppm Cd + 6000 ppm NaCl in Soil) in Table 3(D).

Correlation between Plant Cd Concentration and Dry Biomass

Figure 2 show correlations between dry biomass of different parts (root, stem and leaves) of *Ricinus* plant species with Cd concentration. The negative correlation between dry biomass and Cd concentration in *Ricinus* plant was significant in roots and leaves. In *Sarcococca* plant the negative correlation between root dry biomass with Cd concentration in roots was found significant (Figure 2).

Discussion

Salinity is one of the major problem for crops across the globe. Presence of high salt concentration cause physiological drought condition in plants. Salinity in soil affect plants by reducing water potential, ionic balance/disturbances in ion homeostasis. Since salt stress causes both osmotic as well as ionic stress and thus induce reduction in growth (Sirguey2013).

The presence of Cd in soil further worsen the problem. Cadmium significantly decreased the growth and biomass of studied plants. Soil contaminated with Cd reduces nutrient uptake and translocation into various parts of a plant (Hernandez *et al.* 1996). High concentration of Cd in plant tissues results in the inhibition of several important enzymes (Ouarili *et al.* 1997), affecting respiration and photosynthesis (Vassilev and Yordanov, 2002) and disturb stomatal opening (Barcelo and Poschenrieder1990) and roots elongation (Chen *et al.* 2000).

The present result showed a decrease in plant growth and biomass due to Cd toxicity. Many reports conform the decreasing effect of cadmium on plants growth and biomass (Abu-Muriefah2008; Zheng *et al.* 2010). In the present result, Cd significantly reduced the plant growth, total water content (TWC) and biomass, the same result have been presented by

Rubio *et al.* (1994) who reported that plant growth was reduced by Cd uptake and its distribution within cells. According to Khatamipour *et al.* (2011) Cd affects plant growth by damaging membrane permeability and elongation of cell. Similar findings also reported by Shafiq *et al.* (2008). Combination of salt (NaCl) and Cd further reduced growth and biomass in all the plants.

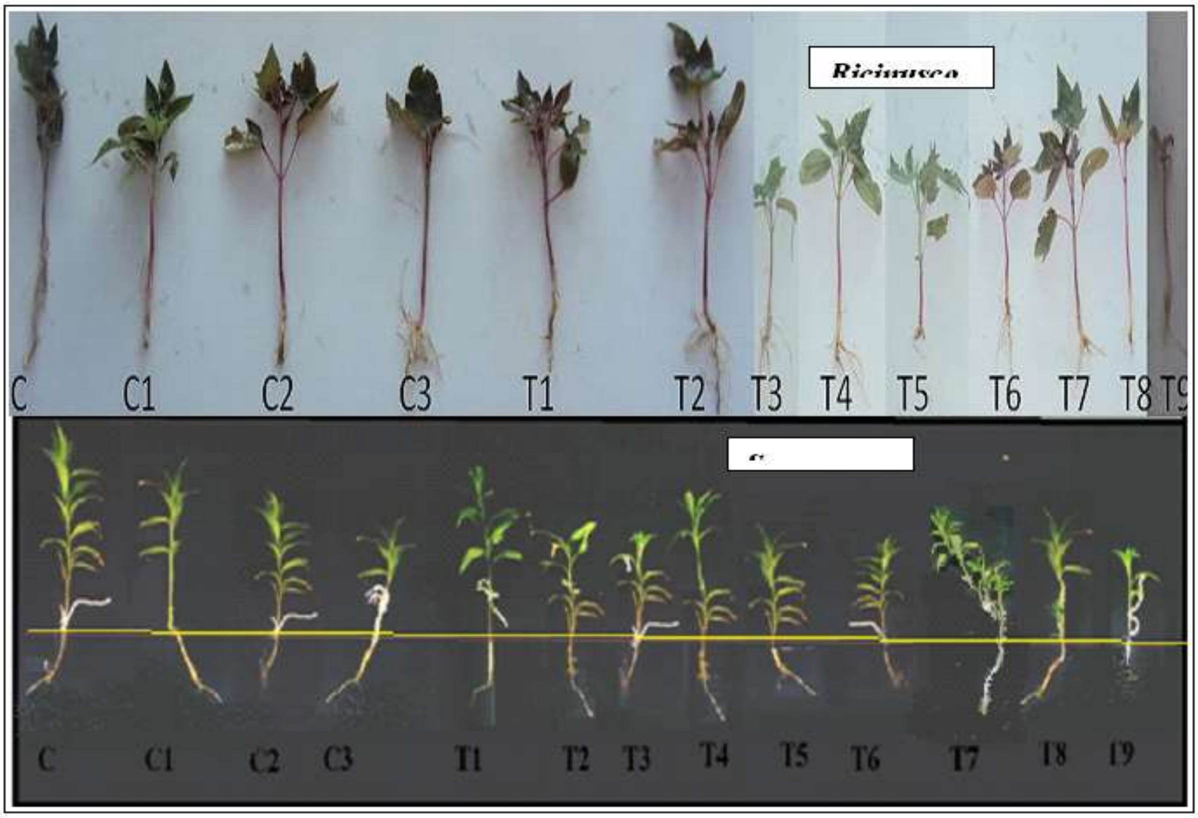

Fig. 1. Effect of different treatments on plants growth. C (Soil without Cd and NaCl addition),C1, C2, C3 (50, 100, 150 ppm Cd in Soil), T1, T2, T3 (1000, 3000, 6000 ppm NaCl + 50 ppm Cd with each NaCl concentration), T4, T5, T6 (1000, 3000, 6000 ppm NaCl + 100 ppm Cd), T7, T8, T9 (1000, 3000, 6000 ppm NaCl + 150 ppm Cd).

Our results showed that salt (NaCl) demonstrated increasing effect on Cd absorption and accumulation within plant tissues. High Cd accumulation in plant might be due to two mechanisms *i.e.* exchange of metals from sorption sites in soil by the cationic component and formation of stable metal complexes with the chloride anion (Schmidt, 2003). Addition of NaCl increased Cd concentration in the soil solution and accumulation in the leaf of Swiss chard and potato tubers (Mc Laughlin *et al.*, 1994; Smolders *et al.*, 1998). Highest salt concentration in soil was found most significant in terms of Cd concentration in plants.

Phytoremediation is a right choice which is applicable to soil contaminated with different types of pollutants. Laboratory and field trials have proven successful, but this ideal technique is in all cases dependent on plant growth ability on low-fertility soil. While contaminant concentration has often been proposed as an explanation for plant growth limitation, other factors, commonly occurring in industrial soils, such as salinity, should be considered.

In order to achieve the goal, the accumulation of Cd via root uptake at different saline conditions were investigated as there is notable evidence that salinity is a key factor in the translocation of metals from roots to the aerial parts of the plant (Manousaki and Kalogerakis, 2009).

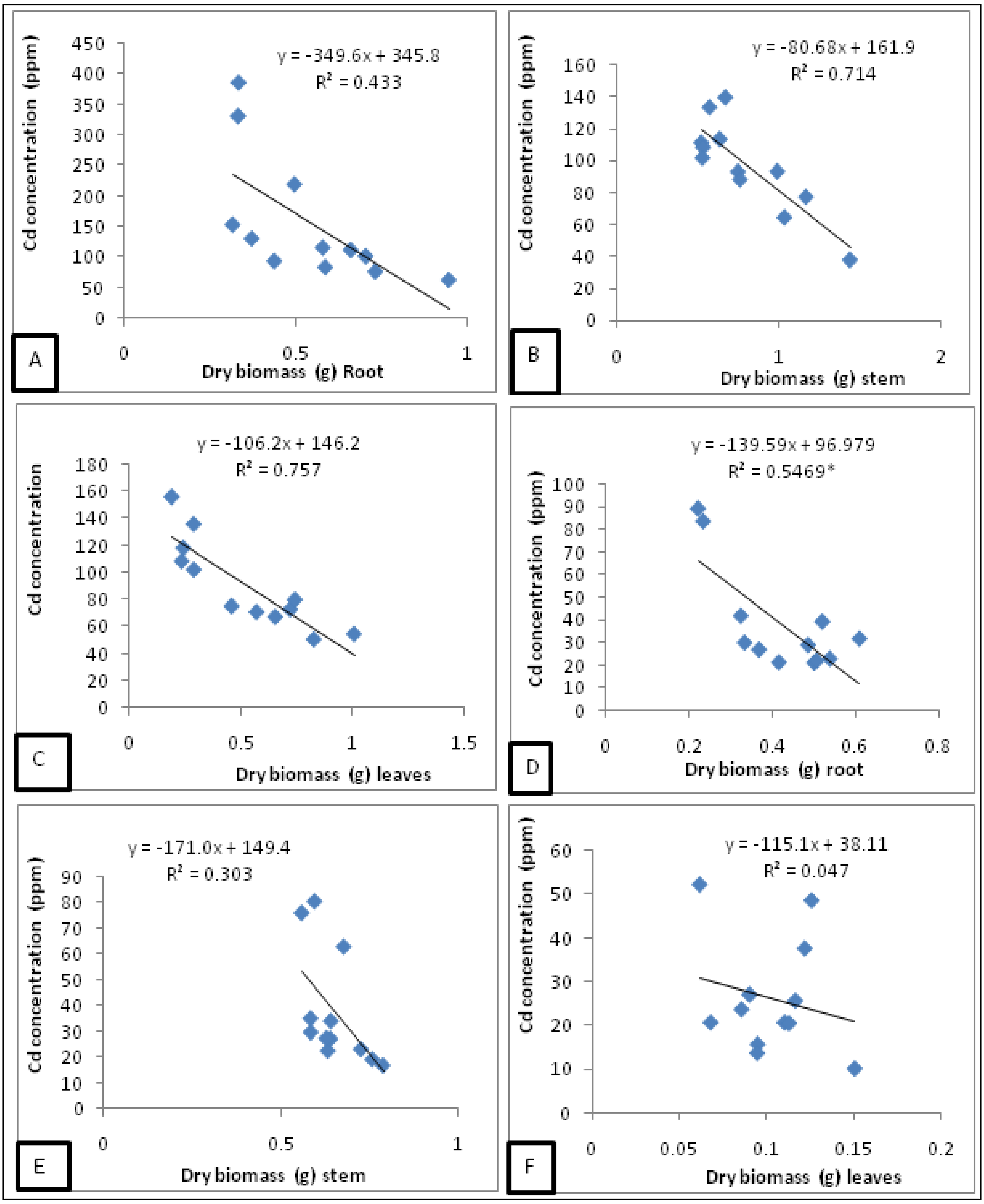

Fig. 2. Correlation between dry biomass and Cd concentration within different parts of *Ricinus* (A,B,C) and *Sarcococca* (D,E,F) plants.

Conclusions

Salinity of soil is a *global problem* and the presence of cadmium further worsen the problem. High concentration of salt (NaCl) in soil was found to increased concentration of Cd in plants tissues. *Ricinus communis* plant showed higher Cd bioaccumulation as compared to *Sarcococca saligna* plant. Biomass in all the plants were highly decreased by the combination treatments of Cd and salt. Although high concentration of NaCl in soil increased Cd uptake and accumulation in the plants, while decreased biomass of all the plants.

Acknowledgements

The present research work was financially supported by Higher Education Commission of Pakistan under the indigenous PhD scholarship program.

References

Abu-Muriefah SS. 2008. Growth parameters and elemental status of cucumber (*Cucumus sativus*) seedlings in response to cadmium accumulation. International Journal of Agriculture and Biology **10,** 261–266.

Ali, N, Hadi F. 2015. Phytoremediation of cadmium improved with the high production of endogenous phenolics and free proline contents in *Parthenium hysterophorus* plant treated exogenously with plant growth regulator and chelating agent. Environmental Science and Pollution Research **22(17),** 13305-13318.

Allen SE. 1974. Chemical analysis of ecological materials. Blackwell Scientific Publication, Oxford, London.

Barcelo J, Poschenrieder C, 1990. Plant water relations as affected by heavy metal stress: a review. Journal of Plant Nutrition **13,** 1-37.

Chen ZS, Lee GJ, Liu JC. 2000. The effects of chemical remediation treatments on the extractability and speciation of cadmium and lead in contaminated soils. Chemosphere **41,** 235–242.

Hadi, F, Ali N, Ahmad A. 2014. Enhanced Phytoremediation of Cadmium-Contaminated Soil by *Parthenium hysterophorus* Plant: Effect of Gibberellic Acid (GA3) and Synthetic Chelator, Alone and in Combinations. Bioremediation Journal **18(1),** 46–55.

Hernandez LE, Carpena-Ruiz R, Garate A. 1996. Alterations in the mineral nutrition of pea seedlings exposed to cadmium. Journal of Plant Nutrition and Soil Science **19,** 1581-1598.

Khatamipour M, Piri E, Esmaeilian Y, Tavassoli A. 2011. Toxic effect of cadmium on germination, seedling growth and proline content of Milk thistle (*Silybum marianum*). Annual Biological Research **2,** 527-532.

Manousaki E, Kalogerakis N. 2009. Phytoextraction of Pb and Cd by the Mediterranean saltbush (*Atriplex halimus* L.): metal uptake in relation to salinity. International journal of Environmental science and pollution research1 **6(7),** 844-854.

McLaughlin MJ, Tiller KG, Beech TA, Smart MK. 1994. Soil salinity causes elevated cadmium concentrations in field- growth potato tubers. Journal of Environmental Science **23,** 1013- 1018.

Ouarili O, Boussama N, Zarrouk M, Cherif A, Ghorbal MH. 1997. Cadmium and copper- induced changes in tomato membrane lipids. Phytochemistry **45,** 1343-350.

Rubio MI, Escrig I, Martínez-Cortina C, Lopez-Benet FJ, Sanz A. 1994. Cadmium and nickel accumulation in rice plants: effects on mineral nutrition and possible interactions of abscisic and gibberellic acids. Plant Growth Regulation1 **4(2),** 151–157.

Saberi M, Shahriari A. 2011. Investigation the Effects of Cadmium Chloride and Copper Sulfate on Germination and Seedling Growth of *Agropyron elongatum*. Modern Applied Science **5(5),** 232-243.

Sairam RK, Tygai A. 2004. Physiology and molecular biology of salinity stress tolerance in plants. Current Science **86,** 407-421.

Schmidt U. 2003. Enhancing phytoextraction: The effect of chemical soil manipulation on mobility, plant accumulation and leaching of heavy metals. Journal of Environmental Quality **32,** 1939-1954.

Shafi MJ, Bakht Raziuddin Y, Hayat, Zhang G. 2011. Genotypic differences in the inhibition of photosynthesis and chlorophyll fluorescence by salinity and cadmium stresses on stresses in wheat. Journal of Plant Nutrition **34,** 315-23.

Shafiq M, Iqbal MZ, Athar M. 2008. Effect of lead and cadmium on germination and seedling growth of *Leucaena leucocephala*. Journal of Applied Science and Environmental Management **12(2),** 61-66.

Sirguey C, Ouvrard S. 2013. Contaminated soils salinity, a threat for phytoextraction. Chemosphere **91(3),** 269-274.

Smolders E, Lambregts RM, Mclaughlin MJ, Tiller KG. 1998. Effect of Soil Solution Chloride on Cd Availability to Swiss Chard. Journal of Environmental Quality **27(2),** 426–431.

Vassilev A, Lidon F, Matos MDC, Ramalho JC and Yordanov I. 2002. Photosynthetic performance and content of some nutrients in cadmium- and copper-treated barley plants. Journal of Plant Nutrition **25,** 2343-60.

Viégas RA, Silveira JAG, Lima Júnior, Queiroz AR, Fausto JE. 2001. Effects of NaCl-salinity on growth and inorganic solute accumulation in young cashew plants. *Revista Brasileira* de *Engenharia agrícolae*. Ambiental **5,** 216-222.

Zheng G, Lv HP, Gao S, Wang SR. 2010. Effects of cadmium on growth and antioxidant responses in *Glycyrrhiz auralensis* seedlings. Plant, Soil and Environment **56,** 508-515.