Title
Crop growth as influenced by Zinc and organic matter in Cadmium-rich polluted soils

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Introduction

Growing vegetables by using city wastewater, industrial effluent etc. as a sole source of irrigation and as fertilizer supplement is a common practice in the vicinity of big cities. Such a practice leads to accumulation of toxic metals like Ni, Cd, and Cr etc. in the soil as well as the crop plants, which affect the food chain. Green leafy vegetables accumulated highest amount of Pb, Ni and Cd in crops in sewage irrigated areas followed by roots, tubers and lowest in cereal crops (Setia et al. 1998). A constant anthropogenic release of Cd to the environment has resulted in a continuous build up of Cd in soils. Some heavily contaminated soils are confined to areas of non-ferrous metal mining and production (Shenker et al 2001). Other wide spread regions are subject to moderate input of anthropogenic Cd through activities such as waste incineration, sewage sludge application and use of phosphatic fertilizers. A concern was raised that the uptake and accumulation of Cd in plant tissues and grains might lead to food chain transfer to humans (Gupta and Gupta 1998).

Singh and Nayyar (1989) found that effect of Cd and Zn on corn yield became antagonistically related and application of Cd also increased the Zn availability to corn. Georgieva et al (1997) reported that Cd toxicity depends more on free Cd^{2+} ions than on total tissue Cd content and the combination of Cd, Zn decreases tissue Cd content of radish, pea and pepper plants. Khan and Khan 1983 reported that increasing rates of Cd application decreased most of the nutrients i.e. Mn, Zn, Fe, Cu and Na contents of the eggplants and Zn in tomato.

DTPA extractable metals like Cd^{2+} were decreased by increased rate of organic matter application irrespective of its source. Barring some indications in the literature that application of farmyard manure significantly reduces the content as well as the uptake of Cd, little information is available concerning the behaviour of FYM in counteracting the harmful effects of excess pollutant elements when present together.

Spinach is one of the commonly grown leafy vegetables in India and which is known to be accumulated high amount of these heavy metals due to its leafy growth. The present study was, therefore, undertaken to access interactive effects of Cd and Zn upon spinach yield, uptake and content of Cd and Zn in presence and absence of organic matter.

Materials and Methods

The experimental soil was sandy loam (Typic ustochrept) with pH 7.8, electrical conductivity 0.20 dS m^{-1}, organic carbon 0.56% and DTPA-extractable Cd 0.030 mg kg^{-1}. It was air-dried and ground to pass through a 2mm sieve. Then the soil treated with 0, 10, 20, 40 mg Cd kg^{-1} (as $CdCl_2 \cdot 2H_2O$) & 0, 20, 40, 80 mg Zn kg^{-1} as $ZnSO_4 \cdot 7H_2O$) & equilibrated for 21 days and transferred to earthen pots lined with polyethylene sheet. The treatments were replicated thrice in a completely randomized design. The soil in all the pots received basal dose of N (65 mg N kg^{-1}) as urea and P (30mg P_2O_5 kg^{-1}) and potassium di-hydrogen orthophosphate.

Fifteen seeds of spinach were sown per pot and the pots were irrigated with deionised water as and when required. After establishment of seedlings they were thinned to 7 plants per pot. The crops were grown for 45 days and then harvested. After harvesting the crop at 45 days growth, the green yield was recorded and the soil samples were collected from every pot and analyzed for DTPA-extractable Cd & Zn. The harvested plant samples were washed sequentially with tap water, acidulated water (0.01N HCl), distilled water and deionized water. They were then air-dried followed by oven drying at 60-65^{0}C to a constant weight. After recording the dry matter yield of the shoots, the samples were ground in a Wiley mill with stainless steel blades to pass through a 40-mesh sieve and then digested in di-acid mixture of HNO_3 and $HClO_4$ (in 3:1 ratio). Cadmium & Zn content in the plant digests and the soil extracts was then estimated on atomic absorption spectrophotometer (Issac and Gerber 1971).

Results and Discussions

Crop yield as influenced by Cd, Zn and FYM

Dry matter yield decreased progressively with increasing levels of Cd at all levels of Zn application. Application of Zn caused an increase in the dry matter yield of spinach at all levels of Cd application. Addition of FYM caused an increase in the dry matter yield of spinach, irrespective of the levels of Cd and Zn.

The decrease in the dry matter yield with increasing rates of Cd application might be due to adverse effect of Cd on the energy producing mechanism of chloroplasts and mitochondria (Das 2000). Clarkson and Lutge (1989) reported that Cd damages the biomembrane and cause enzymatic changes and possible interaction with macro and micro-elements leads to the phytotoxicity of this element. The decrease in yield with increasing rates of Cd application was also reported by Sarkunan et al 1996 in rice; Georgieva et al (1997) in radish, pea and peeper; Ozturk et al 2003 in wheat; Singh and Kansal (1990) in maize.

The addition of Zn enhanced the DMY of spinach by reducing its content in the soil, thereby reducing its uptake. Similar results were also obtained by Singh and Nayyar (1989) in corn; Sarkunan et al (1996) in rice; Georgieva et al (1997) in radish, pea and peeper and Gupta and Potalia (1990) in wheat.

Farmyard manure also enhanced the DMY of spinach by reducing Cd concentration in soil by forming complex with it. As the content of Cd in shoot decreases that leads to the less phytotoxicity and better DMY of the crop.

Cadmium concentration:

An increasing supply of Cd resulted in increase in Cd concentration of spinach. The mean increase was 2.40-µg g^{-1} at control and 15.36-µg g^{-1} at 40 mg Cd kg^{-1} soil application (Table 2). Upon addition of Zn, the Cd^{2+} concentration of the shoot decreased. The mean decrease was 15.36 at control and 12.91µg g^{-1} at 80 mg Cd kg^{-1} soil application.

Cadmium concentration of the shoot also decreased upon the addition of FYM. But the comparison of the data showed that the combined effect of FYM and Zn reduce the Cd content most than the single application of both. Sarkunan et al 1991 reported that addition of compost reduced the Cd content of rice. According to Kuo et al (1985) organic matter had little effect on Cd availability in soil.

Since both Zn and Cd have almost similar ionic radii, the simultaneous addition of both Cd and Zn reduced the adsorption of both ions. The interaction of Cd with Zn in plants is based on the substitution of Cd with Zn and decrease in Cd below its phytotoxic concentration in tissues (Purvis 1985; Kabata-Pendias and Pendias 1989). The application of Zn in soils decreased the concentration of Cd in the soil and subsequently decreased the content and uptake of Cd by the plants, which was also, suggested an antagonistic relationship between them (Das and Kumar 1996).

Concentration of Zn

Upon addition of Cd, the Zn concentration of spinach increased. The mean increase in Zn concentration was 2.4 at control and 33.3 µg g^{-1} at 40 mg Cd kg^{-1} soil. FYM application also enhanced the Zn concentration of the shoot. The combined effect of Cd and FYM enhanced the Zn content of the spinach better than the individual application of both.

The increased Zn concentration in plant with Cd application might have been arisen due to greater dissociation of Zn from the binding sites due to competition for the same sites, thus increasing Zn concentration in soil solution (Singh and Nayyar 1991).

Cadmium Uptake

There was a significant increase in the uptake of Cd with its increasing rates of application (Fig 1). The mean increase was 15.36 µg pot^{-1} in control to 149.33 µg pot^{-1} with 40 mg Cd kg^{-1} soil. The Cd uptake experienced the similar increasing trends, in presence of Zn irrespective of its rates of application but the uptake was less than that of the single application of Cd. It might be due to the decrease in Cd content of the shoot when Zn was added in increasing rates (Table 2). The Cd uptake was decreased upon the addition of Zn irrespective of the presence of Cd. On an average it was decreased from 75.16 µg pot^{-1} in control to 76.18, 63.91 and 58.47 at 20, 40 and 80 mg Zn kg^{-1} soil application.

Addition of FYM increased the Cd uptake up to 20 mg kg^{-1} soil and there after it was decreased irrespective of the presence of Zn. The application of FYM, increased the shoot DMY due to less Cd availability to spinach by formation of metal complex, leads to the increase in the uptake of Cd up to 20 mg kg^{-1} soil. When FYM added along with Zn the uptake of Cd declined irrespective of the presence of Cd.

Zinc uptake

Zinc uptake increased with increased rates of Zn application and was decreased with increased rates of Cd application (Fig 2). Addition of Cd decreased the Zn uptake significantly at all levels of its application irrespective of the presence of Cd.

Addition of FYM significantly increased the Zn uptake irrespective of the presence of Zn and Cd. There was an overall increase of 17.85 % when FYM is applied along with Cd and Zn compared to no FYM applied pots.

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Table 1: Dry matter yield (g/pot) as influenced by Cd and Zn application in presence and absence of FYM

		Zn (mg/ kg)				
FYM (%)	**Cd (mg/ kg)**	0	20	40	80	Mean
	0	6.49	6.57	6.48	6.46	**6.51**
	10	5.52	5.82	5.89	5.92	**5.78**
0	20	5.13	5.39	5.48	5.52	**5.38**
	40	4.51	4.82	4.92	4.98	**4.81**
	Mean	**5.39**	**5.65**	**5.69**	**5.72**	***5.62***
	0	7.52	7.58	7.5	7.53	**7.53**
1%	10	6.27	6.93	6.98	7.08	**6.81**
	20	5.7	5.9	5.96	6.12	**5.92**
	40	4.89	4.99	5.14	5.22	**5.06**
	Mean	**6.09**	**6.35**	**6.39**	**6.48**	***6.33***
Cd (p=0.05)		Cd=0.092 Zn= 0.092 CdxZn= 0.187 FYM= 0.065				
		Cd XFYM= NS Zn X FYM= NS				

Table 2: Cadmium concentration (µg/g) of shoot as influenced by Cd and Zn application in presence and absence of FYM

		Zn (mg\kg)				
FYM (%)	**Cd (mg/ kg**	0	20	40	80	Mean
	0	2.4	2.24	2.12	1.91	**2.16**
	10	7.52	7.38	7.16	7.02	**7.27**
0	20	18.22	17.63	16.78	16.43	**17.26**
	40	33.3	30.6	28.86	26.3	**29.76**
	Mean	**15.36**	**14.46**	**13.73**	**12.91**	
	0	2.12	2.05	1.86	1.67	**1.92**
1%	10	7.31	7.18	7.04	6.79	**7.08**
	20	17.14	16.5	16.1	15.4	**16.28**
	40	30.3	28.1	24.96	21.4	**26.19**
	Mean	**14.21**	**13.46**	**12.49**	**11.31**	
Cd (p=0.05)		***Cd=0.105 Zn= 0.105 CdxZn= 0.211 FYM= 0.074***				
		Cd X FYM= 0.15 Zn X FYM= NS				

Table 3: Zinc concentration (µg/g) of shoot as influenced by Cd and Zn application in presence and absence of FYM

		Zn (mg/kg)				
FYM (%)	Cd (mg/ kg)	0	20	40	80	Mean
	0	28.99	44.8	72.66	95.42	**60.46**
	10	32.2	47.94	76.36	98.53	**63.75**
0	20	36.3	52.4	81.23	101.36	**67.82**
	40	42.7	57.6	85.7	105.6	**72.9**
	Mean	**35.04**	**50.68**	**78.98**	**100.22**	***66.23***
	0	33.48	50.2	78.67	98.33	**65.17**
1%	10	34.5	52.93	81.26	103.3	**67.99**
	20	41.3	54.26	84.53	106.6	**71.67**
	40	46.2	61.6	88.4	110.8	**76.75**
	Mean	**38.87**	**54.74**	**83.21**	**104.75**	***70.40***
Cd (p=0.05)		***Cd=0.270 Zn= 0.270 Cd x Zn= 0.541 FYM= 0.191***				
		CdXFYM= 0.383 Zn X FYM= 0.383				

Figure 1: Cd uptake as influenced by Cd and Zn application in presence and absence of organic matter

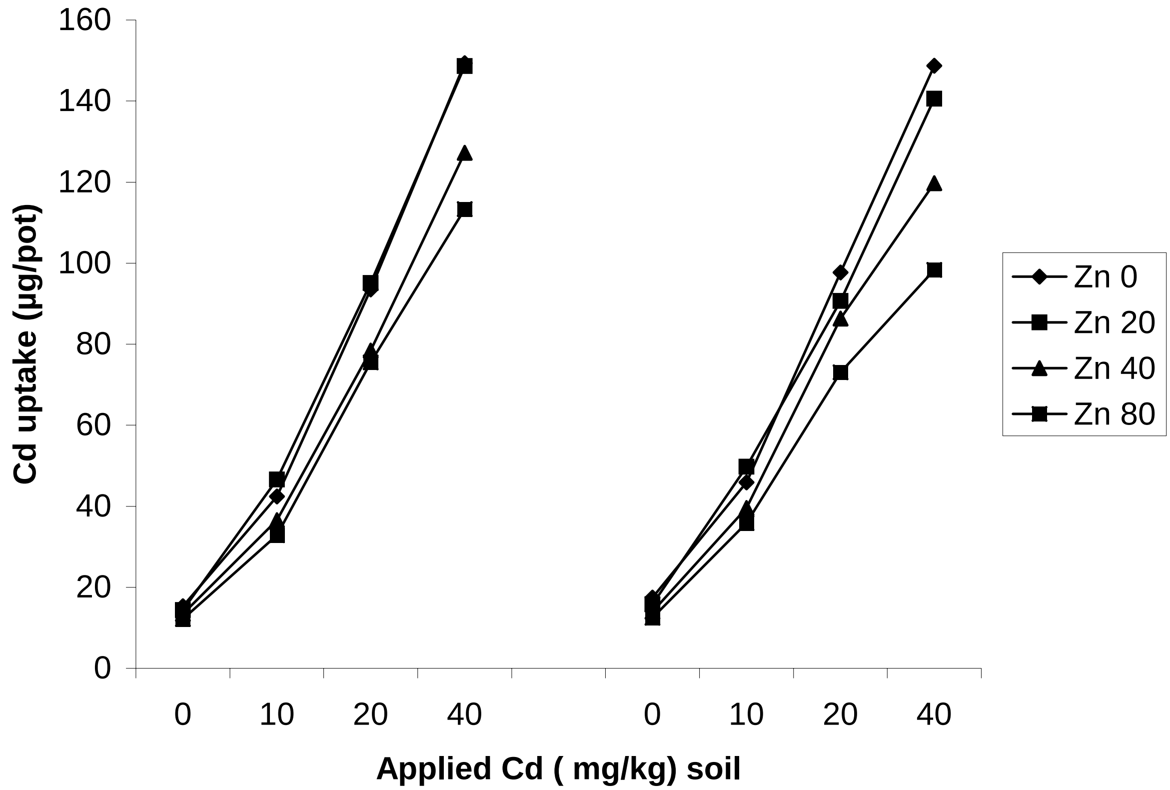

Figure 2: Zinc uptake as influenced by Cd and Zn in presence and absence of organic matter