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Short communication

Effect of chromium on root morphology of leafy vegetables: Spinach and cabbage

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ABSTRACT

The effect of chromium (Cr) supplemented irrigation water on particular root morphological characteristics of two leafy vegetables, namely spinach and cabbage were studied in a pot culture experiment. The results showed that at 7.5 mg l^{-1} Cr level in irrigation water, the spinach did not survive inspite of germination. In spinach, root fresh weight was reduced from 26.9 (control) to 8.02 g $plant^{-1}$ (0.5 mg l^{-1} cv), although it was reduced in cabbage from 26.3 (control) to 19.1 g $plant^{-1}$ (0.5 mg l^{-1} cv) prior to 15.23 g $plant^{-1}$ (7.5 mg l^{-1} cv). The presence of 0.1 mg l^{-1}Cr in irrigation water, marginally increased root surface area, root volume and root tips in spinach, but in cabbage, these were significantly reduced. In both the crops, root morphological parameters in response to higher level of Cr exposure were significantly decreased. It is suggested that spinach being slightly tolerant as compared to cabbage could be grown in irrigation water with low level Cr (< 0.1 mg l^{-1}).

Key words: Cabbage, spinach, irrigation water, Cr sensitivity.

Chromium is a toxic carcinogen and released in soil mainly from leather tanning, textile, carpet and electroplating industries. Chromium (Cr) is a non essential and toxic element to plants (Pandey and Pandey, 5). Chromium is biomagnified at different trophic levels *via* its accumulation in producers of food chain (Rai *et al.*, 6). Tang *et al*. (8) reported that dry weight of the tea root and stem and new leaves decreased with increasing Cr contamination in soil. India is the second largest producer of vegetables, contributing about 12.3 per cent to the world vegetable production. India ranks third in the production of cabbage (Kumar, 4). Presently it occupies 7.98 million hectare area with the annual production of 133.74 million tonnes. Cabbage are most preferred winter vegetables and their total share in the country's vegetable production is 5.3% (IIVR, 3). However, reports regarding effects of Cr on root structure are very few. Hence, the present study was aimed to investigate the effects of Cr on root morphology and yield of spinach and cabbage.

The experiment was conducted in the net house of Water Technology Center, IARI, New Delhi, on two leafy vegetables, *viz*. spinach (variety Pusa Bharti) and cabbage (variety Golden Acre) in the *rabi* season of year 2008-2009 and 2009-2010. Twenty five-day-old cabbage seedlings were transplanted in each plastic pot. In the case of spinach, direct sowing of twenty seeds was done. The pot (size 30 cm × 30 cm) was filled with 15 kg of thoroughly mixed, air-dried, 2 mm sieved sandy loam soil including FYM for the experiment. The initial soil pH, EC, moisture percent, organic carbon, available nitrogen, phosphorus, potassium, DTPA-Zn, Fe and DTPA-Cr contents were 7.9, 0.36 dS m^{-1}, 4.59%, 0.30%, 180 kg ha^{-1}, 13.7 kg ha^{-1} and 133.3 kg ha^{-1}, 1.35 mg kg^{-1}, 3.80 mg kg^{-1} and 0.055 (mg kg^{-1}), respectively. Recommended doses of fertilizers (urea, single super phosphate and muriate of potash) were applied to all the treatments. In spinach, the dosage of N, P_2O_5 and K_2O was 15.3, 31.39 and 2.51 g pot^{-1}, while in cabbage it was 1.64, 3.77 and 1.0 g pot^{-1}, respectively. The crops were exposed to different concentration (0.0, 0.1, 0.5, 2.5 and 7.5 mg l^{-1}) of chromium sulphate [$Cr_2(SO_4)_3.6H_2O$] dissolved in tap water.

The experiment was laid out in a completely randomized block design (CRD) in triplicates.The irrigation was given with Cr supplemented water at 3-5 day intervals or when needed in both spinach and cabbage crops. The root samples were collected after the harvest. Removal of soil from rhizosphere was done carefully with the help of water pressure. Root samples were oven-dried at 65°C for dry weight. After drying, the samples were analyzed for other root morphological characteristics with help of root scanner (Epson Model EU-22) equipped with Win Rhizo software. Statistical analysis of each parameter was subjected to one way analysis of variance (ANOVA) and Duncans's Multiple Range Test (DMRT) at $p<0.05$ for separation of means using window based SPSS 16.0 statistical package.

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The root morphological parameters of spinach and cabbage decreased significantly due to successive higher doses of Cr (Table 1). In the case of spinach, it was also noted that the treatment containing 7.5 mg l^{-1} Cr concentration, in spite of germination the crop did not survive further, while in the treatment containing 0.1 mg l^{-1} Cr concentration, the root surface area, root volume and root tips increased marginally by 2.78, 8.73 and 5.85 percent, respectively. The reduction in root length, root surface area and root volume in spinach was 89.5, 90.7 and 76.9%, respectively in treatment containing 2.5 mg l^{-1}Cr concentration as compared to control and in the case of cabbage, the above parameters deceased by 64.1, 78 and 93% in the same order. On the other hand, the treatment containing 7.5 mg l^{-1}Cr concentration, these parameters in cabbage were deceased by 79, 86.6 and 96.3%, respectively.

In spinach, at 2.5 mg l^{-1}Cr concentration, the root length density, root tips, root forks and root crossings decreased by 89.5, 91.9, 96.1 and 97.6%, respectively (as compared to control). In the case of cabbage, the above parameters decreased by 66.8, 66.9, 84.0 and 85.3%, respectively (as compared to control). The above parameters in cabbage were reduced by 83.3, 79.8, 88.5 and 92.5%, respectively (as compared to control) due to Cr dose of 7.5 mg l^{-1}. Fresh and dry weight of root in spinach and cabbage were decreased significantly due to Cr treatments (Fig. 1). Fresh weight of spinach was decreased by 70.1% due to treatment containing 2.5 mg l^{-1} Cr, while in the case of cabbage, it was found to be decreased by 27.2% at 2.5 mg l^{-1} and 42.0% at 7.5 mg l^{-1}Cr. Dry weight of spinach was decreased by 90% in treatment containing 2.5 mg l^{-1} Cr, while it was decreased by 42.4% in cabbage and 60.8% at 7.5 mg l^{-1} Cr.

The result on root morphological characteristics and yield suggested that spinach was more sensitive than cabbage under Cr contamination in irrigation water. However, at low level of Cr in irrigation water, spinach crop was benefitted by enhanced root surface area, root volume and root tips. This might be due to presence of some tolerance mechanism in spinach, which helped to withstand low level of Cr concentration. Earlier, Samantaray *et al*. (7) reported that at 0.2 mg l^{-1}Cr concentration, the yield of soybean was unaffected. However, majority of the reports suggested that in general the field crops were adversely affected by higher levels of Cr concentration (Turner and Rust, 9; Devis *et al.*, 1). Hayat *et al*. (2) reported that Cr toxicity in plants affects growth and development of roots, which could decrease total biomass production and yield.

From the results, it may be concluded that spinach being slightly tolerant to Cr as compared to cabbage, can be grown with irrigation water with 0.1 mg l^{-1} Cr. Spinach and cabbage, both being leafy vegetables are advised not to grow with irrigation water at higher levels of Cr as consumption of these vegetables could cause food chain contamination in long term.

Table 1. Spinach and cabbage root morphological characteristics with different concentrations of chromium (Cr) in irrigation water.

Parameter	Crop	Cr conc. (mg k^{-1})				
		Control	0.1	0.5	2.5	7.5
Root length (cm $plant^{-1}$)	Spinach	1910.2^{a}	1333.3^{b}	1253.3^{b}	201.1^{c}	-
	Cabbage	817.7^{a}	805.4^{a}	611.7^{b}	293.4^{c}	171.9^{d}
Root surface area (cm^2 $plant^{-1}$)	Spinach	824.1^{a}	847^{a}	557.3^{b}	77^{c}	-
	Cabbage	870.3^{a}	828.7^{a}	177.8^{bc}	191.6^{b}	117^{c}
Root volume (cm^3plant^{-1})	Spinach	30.35^{a}	33^{ab}	26.77^{b}	7^{c}	-
	Cabbage	83.67^{a}	77.02^{b}	70.13^{c}	5.84^{d}	3.11^{d}
Root length density (cm^2 m^3plant^{-1})	Spinach	1908.6^{a}	1895.7^{a}	1118^{b}	200.9^{c}	-
	Cabbage	882.3^{a}	884.3^{a}	471.2^{b}	293.4^{c}	147.0^{d}
Root tips ($plant^{-1}$)	Spinach	3778^{a}	3999^{a}	1080^{b}	305^{c}	-
	Cabbage	3136^{a}	3400^{b}	1647^{c}	1040^{d}	635^{e}
Root forks ($plant^{-1}$)	Spinach	11021^{a}	10398^{a}	1034^{b}	434^{b}	-
	Cabbage	8927^{a}	7265^{b}	2577^{c}	1428^{d}	1030^{d}
Root crossings ($plant^{-1}$)	Spinach	3440^{a}	3347^{a}	2359^{b}	83^{c}	-
	Cabbage	2781^{a}	2268^{b}	923^{c}	410^{d}	210^{d}

Different letters indicate significant difference between means at *P≤0.05* (DMRT)

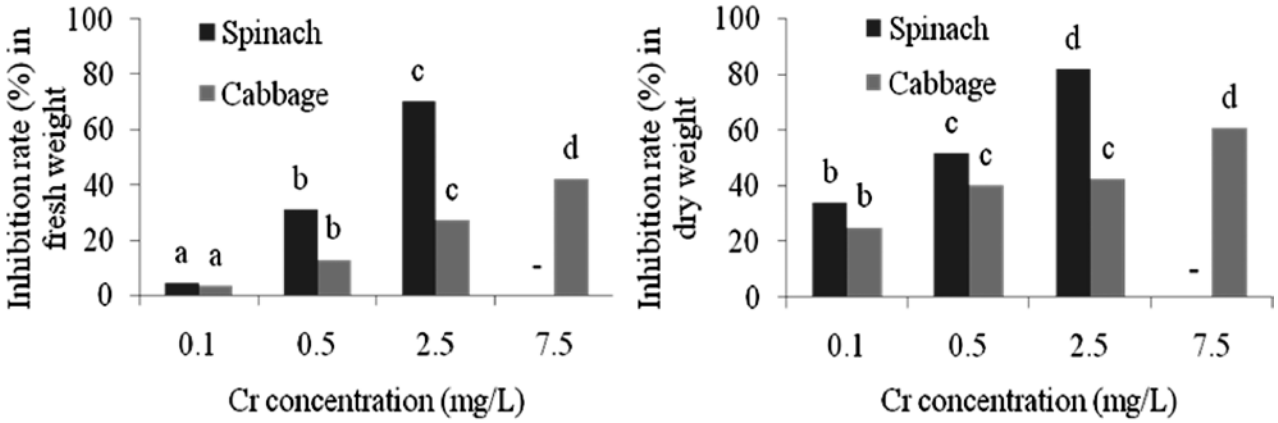

Fig. 1. Inhibition rate of fresh and dry weight in spinach and cabbage under different Cr concentration. Bar followed by the different letter are significant (p≤0.05) by Duncan's Multiple Range Test (DMRT).

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