

Article

Growth and Nutrient Uptake of Paddy (*Oryza sativa* L.) under Chromium(VI) Treatment

M. Nagarajan ^{1, *}, K. Sankar Ganesh ²

¹ Research and Development Centre, Bharathiyar University, Coimbatore-641046, India

² Department of Botany, A.V.C. College, Mannampandal, Mayiladuthurai, India

* Author to whom correspondence should be addressed; E-Mail: smnavc@gmail.com.

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Abstract: Chromium is a heavy metal, and considered as an environmental hazard. Toxicity effects of chromium on growth and development of plants including inhibition of germination process, and decrease of growth and biomass of plant. The aim of this research is to study accumulation of chromium along with nutrients and its effect on the growth of paddy plant (*Oryza sativa* L.). Thus, paddy seedlings grown in petriplates lined with filter paper undergoing, different treatments of Cr (0, 2.5, 5, 10, 25, 50, 75, 100 and 200 mg/L). After one week seedlings were removed and morpho physiological parameters like root length, shoot length and dry weight of plants and accumulation of nutrients along with Cr in roots and shoots were determined. The results indicated that the concentrations more than 100 mg/L chromium cause the reduction of morphophysiology parameters in the treatment plants rather than control plant and Cr addition in the cultures caused enhancement of chromium content in roots and shoots of plant seedlings. Similarly nutrient accumulation was also affected by increasing concentrations of chromium. It was also noted that accumulation of chromium in the roots was much higher than the shoots of the seedlings under treatment.

Keywords: paddy; growth; heavy metal; chromium; accumulation.

1. Introduction

The problem of water pollution due to industrial effluents has already become a serious threat in India. The effluent discharging industries are distilleries, detergents, electroplating plants, fertilizer units, iron and steel industries, paper and pulp, pharmaceuticals, petrochemical, pesticides and herbicide industries, oil refineries, sugar mills, thermal power plants, textile, tannery and dye industries. These industrial effluents contain a wide variety of organic and inorganic pollutants with heavy metals which create many serious physiological disorders in living organisms. Chromium is a heavy metal with risk to human health. Its presence in agricultural soils can be attributed to the use of organic wastes as fertilizer and the use of waste water for irrigation (Sankar ganesh *et al*, 2008). Chromium enters the food chain through consumption of plant material. A high concentration of Cr has been found to be harmful to vegetation. As the chromium concentration in plants increases, it adversely affects several biological parameters. Ultimately there is loss of vegetation, and land sometimes becomes barren (Dube *et al.*, 2003). In recent years, contamination of the environment by chromium has become a major concern. Chromium is used on a large-scale in many different industries, including metallurgy, electroplating, production of paints and pigments, tanning, wood preservation, chemical production, and pulp and paper production (Zayed and Terry, 2003). These industries have become especially large contributors of Cr pollution, which can ultimately have significant adverse biological and ecological effects. Very high levels of Cr(VI) contamination (14,600 mg/kg in ground water and 25,900 mg/kg in soil) were reported at the United Chrome Products site in Corvallis, Oregon (Krishnamurthy and Wilkens, 1994). Symptoms of Cr phytotoxicity include inhibition of seed germination or of early seedling development, reduction of root growth, leaf chlorosis and depressed biomass (Sharma *et al.*, 1995). There are many studies on Cr toxicity in crop plants. Chromium significantly affects the metabolism of plants such as barley (*Hordeum vulgare*) (Ali *et al.*, 2004), citrullus (Dube *et al.*, 2003), cauliflower (Chatterjee and Chatterjee, 2000), vegetable crops (Zayed *et al.*, 1998), wheat (*Triticum aestivum* cv. HD2204) (Sharma *et al.*, 1995), maize (*Zea mays*) (Sharma and Pant, 1994) and soy bean and black gram (Sankar ganesh *et al*, 2006). Chromium is highly toxic non-essential element for microorganism and plants (Cervantes *et al.*, 2001). The sources of chromium in environment are both natural and anthropogenic, natural source include burning of oil and coal, petroleum from Ferro chromate refractory material, chromium steels, pigments oxidants, catalyst and fertilizers. This element is also used in metal plating tanneries and oil well drilling (Abbassi *et al.*, 1998). Sewage and fertilizers are also the sources of chromium (Pilay *et al.*, 2003). Marked toxicity of chromium was found with respect to photosynthetic pigment, photosynthesis, nitrate reductase activity and protein content of some alga (Rai *et al.*, 1992). The direct interaction of metal with cellular components can initiate variety of metabolic responses finally leading

to a shift in the development of the plant (Assche and Clijsters, 1990). Chromium toxicity produces chlorosis and necrosis in plants (Cervantes *et al.*, 2001). Several polluting metal and compounds are discharged into the water streams by tanneries. With these aspects in view, the present investigation was made to study the effect of different concentrations of chromium on the growth, mineral nutrients and accumulation of chromium in paddy.

2. Materials and Methods

Paddy (*Oryza sativa* L.) seeds were obtained from the Regional Rice Research Station, Aaduthurai, Tamil Nadu, India. Uniform seeds were selected and surface sterilized with 0.01% HgCl₂ solution for 2 min. Petriplates were lined with filter paper and treated with different concentrations (control, 2.5, 5, 10, 25, 50, 75, 100 and 200 mg/L) of hexavalent chromium. Three replicates were maintained. Plant growth were measured by using centimeter scale and recorded. The same plant samples were taken for morphological studies, which were also used for the determination of dry weight by using electrical single pan balance. Their dry weights were determined by keeping the plant materials in a hot air oven at 80 °C for 24 hrs and recorded. The mineral elements such as total nitrogen (Jackson, 1958), phosphorus (Black, 1965), potassium (Williams and Twine, 1960), calcium and magnesium (Yoshida *et al.*, 1972), manganese, iron, copper, zinc and chromium accumulation was also measured by using the method of Piper, 1966.

3. Results and Discussion

In this experiment, the percentage of germination decreased with the increase of chromium concentrations. In our findings, 200 mg/L chromium concentration reduced the seed germination up to 50 to 60% over control. No germination was recorded beyond 200 mg/L concentration of chromium (Table 1). Similar inhibition of germination percentage at higher concentrations of chromium was observed in soybean (Sidharthan and Lakshmanachary, 1996), mungbean (Rout *et al.*, 1997), cowpea (Lalitha *et al.*, 1999), groundnut (Subramani *et al.*, 1999), blackgram (Lakshmi and Sundaramoorthy, 2003), greengram (Samantary and Deo, 2004) and paddy, blackgram and soybean (Sankar Ganesh *et al.*, 2006b; Sundaramoorthy *et al.*, 2006a,b). The reduction in germination percentage of plants at higher chromium concentrations may be attributed to the interference of metal ions, which may inhibit seed germination by exerting unfavourable effect on the activities of hydrolytic enzymes involved in the mobilization of major seed reservoirs such as starch, protein, RNA and phytin (Dua and Sawhney, 1991).

The root length and shoot length are gradually decreased with the increase in chromium concentrations (Table 1). The highest seedling length was observed in control paddy seedlings. More pronounced effect on seedling growth was observed above 75 mg/L chromium concentrations. The

inhibition of root growth was influenced by the concentration of heavy metals because of the surface accumulation and sensitive to root primordia. It was more pronounced at higher concentrations of chromium (Bitell *et al.*, 1974). In this experiment, there was a gradual decrease in seedling dry weight with the progressive increase in chromium concentrations (Table 1). The lowest dry weight of paddy seedlings was recorded in seedlings treated with 200 mg/L chromium concentration and the highest dry weight was registered at control. The reduction in seedling dry weight was observed from 2.5 mg/L chromium concentrations onwards. A decrease in biomass productivity might be attributed to a disruption in nitrogen metabolism of seedlings under chromium stress (Chatterjee and Chatterjee, 2000).

Table 1. Seed germination, seedling growth (cm/seedling) and seedling dry weight (g/seedling) of paddy (*Oryza sativa* L.) as influenced by different concentrations of chromium

Chromium concentrations (mg/L)	Germination percentage	Root length (cm/seedling)	Shoot length (cm/seedling)	Dry weight (g/seedling)
Control	98.0	10.6 ± 0.424	14.2 ± 0.71	0.256 ± 0.0128
2.5	94.0 (-4.08)	10.4 ± 0.415	13.6 ± 0.65	0.223 ± 0.0126
5	90.0 (-8.16)	9.5 ± 0.325	12.5 ± 0.60	0.173 ± 0.120
10	84.0 (-14.28)	9.2 ± 0.462	11.2 ± 0.07	0.152 ± 0.0116
25	82.0 (-16.32)	9.0 ± 0.423	10.6 ± 0.60	0.143 ± 0.0114
50	74.0 (-24.48)	8.5 ± 0.315	8.7 ± 0.55	0.128 ± 0.0042
75	68.0 (-30.61)	8.0 ± 0.40	7.5 ± 0.45	0.113 ± 0.0038
100	58.0 (-40.81)	5.6 ± 0.315	7.2 ± 0.014	0.098 ± 0.0049
200	52.0 (-46.93)	5.0 ± 0.30	6.0 ± 0.35	0.076 ± 0.0035

Note: Mean ± standard deviation.

The mineral elements such as nitrogen, phosphorus, potassium, calcium, magnesium, manganese, iron, copper and zinc content of paddy are gradually decreased with the increase in chromium concentrations (Table 2). It may be due to competition of chromium ions with potassium, which in turn exercised a regulatory control on potassium uptake (Lanoreaux and Chaney, 1978). The chromium accumulation increased gradually with the increase in chromium concentrations. Among treatments, a higher chromium content of paddy was observed in 200 mg/L chromium concentrations when compared to other chromium treatments. Similarly root accumulate higher amount of chromium than in shoot. It could be due to immobilization of chromium in the vacuoles of the root cells, thus rendering it less toxic, which may be a natural toxicity response of the plant (Shanker *et al.*, 2004a).

Table 2. Nutrient composition and chromium accumulation of paddy (*Oryza sativa* L.) under different concentrations of chromium

Chromium concentrations (mg/L)	N (µg/g)	P (µg/g)	K (µg/g)	Ca (ppm)	Mg (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Chromium (µg/g)
Control	72.0 ± 3.6	18.2 ± 0.91	50.0 ± 2.0	30.0 ± 1.2	20.0 ± 1.0	32.5 ± 1.62	36.2 ± 1.44	16.0 ± 0.85	45.0 ± 1.8	□
2.5	70.5 ± 3.2	16.0 ± 0.88	48.0 ± 2.4	29.0 ± 1.2	18.5 ± 1.0	30.5 ± 1.60	34.5 ± 1.40	15.0 ± 0.80	43.5 ± 1.8	10.5 ± 0.9
5	66.3 ± 3.3	15.5 ± 0.85	47.5 ± 2.37	27.5 ± 1.3	18.0 ± 0.9	28.6 ± 1.55	30.5 ± 1.5	14.5 ± 0.72	40.2 ± 1.6	12.0 ± 1.0
10	60.1 ± 3.0	14.3 ± 0.80	47.0 ± 2.2	25.5 ± 1.2	16.5 ± 0.82	27.2 ± 1.40	29.2 ± 1.5	13.5 0.65	38.5 ± 1.6	16.5 ± 1.0
25	48.5 ± 2.8	12.2 ± 0.70	43.5 ± 2.0	25.0 ± 1.2	16.2 ± 0.80	26.2 ± 1.31	27.5 ± 1.4	13.0 ± 0.60	35.0 ± 1.7	22.2 ± 1.0
50	43.2 ± 2.5	11.5 ± 0.65	35.2 ± 1.8	23.5 ± 1.1	15.0 ± 0.75	24.5 ± 1.30	27.0 ± 1.4	12.5 ± 0.55	33.5 ± 1.5	24.0 ± 1.0
75	36.5 ± 2.5	10.2 ± 0.63	30.2 ± 1.6	22.0 ± 1.1	14.0 ± 0.70	22.0 ± 1.25	25.5 ± 1.3	12.2 ± 0.50	30.2 ± 1.6	25.5 ± 1.2
100	28.2 ± 2.3	9.5 ± 0.66	28.6 ± 1.5	20.2 ± 1.0	12.2 ± 0.60	20.5 ± 1.20	23.0 ± 1.2	10.00 ± 0.50	28.6 ± 1.2	28.2 ± 1.0
200	26.2 ± 2.0	8.2 ± 0.51	24.5 ± 1.5	19.5 ± 0.60	10.1 ± 0.60	20.0 ± 1.10	22.0 ± 1.2	9.2 ± 0.40	27.00 ± 1.2	30.0 ± 1.0

Note: Mean ± standard deviation.

4. Conclusions

It can be concluded that the level of chromium above 200 mg/L is proved to be lethal to paddy crop. However, chromium contaminated water can be properly treated and then discharged into nearby water bodies in order to prevent water pollution. Both government and public sector should join hands in the creation of a clean and green environment.

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