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Toxic effects of chromium on growth of some paddy varieties

M. Nagarajan[1], K. Sankar Ganesh[2]*

[1]Research and Development Centre, Bharathiyar University, Coimbatore - 641 046, India

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

*E-mail address: indsankar@rediffmail.com

ABSTRACT

Chromium is a serious heavy metal and it is considered as an environmental hazard. Toxicity effects of chromium on growth and development of plants including inhibition of germination process decrease of growth and biomass of plant. The aim of this research is to study the accumulation of Cr and its effect on the Germination and growth of some paddy varieties. Thus, the varieties such as ADT-43, ADT-45, IR-50, TKM-9, CO-33, ASD-16 and CO-43 are grown in petriplates treated with different concentrations of Chromium (0, 5, 10, 25, 50, 100, and 200 mg/L). After one week exposure the seedlings were removed and morphophysiological parameters like germination percentage, seedling length and dry weight of paddy varieties and accumulation of Cr were determined. The results indicated that the concentrations more than 100 mg/L chromium cause the reduction of morphophysiological parameters in the treatments rather than control and Cr addition in the cultures caused enhancement of chromium content in roots and shoots of plant seedlings. It was also noted that accumulation of chromium in the roots was much higher than the shoots of the paddy seedlings under treatment.

Keywords: Arsenic; cadmium; chromium; cobalt; copper; lead; mercury; nickel; uranium; vanadium; zinc

1. INTRODUCTION

Water is the most vital resource for all kinds of life on this planet. The problem of water pollution due to industrial wastewater is attaining greater dimension day by day in India. Today, most of the rivers of world receive millions of liters of sewage, domestic waste and industrial and agricultural effluent and gets polluted. The wastewater discharging industries are distilleries, electroplating units, fertilizer units, iron and steel industries, paper and pulp, pharmaceuticals, pesticides and herbicide industries, textile, tannery and dye industries. These industrial effluents contain a wide variety of organic and inorganic pollutants with heavy metals which create serious physico-chemical disorders in living organisms. Heavy metals are the metals which are having a density of five times higher than that of water (Sankar ganesh *et al*.,2006 a).

Arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel, uranium, vanadium and zinc are the some of the important heavy metals found in our environment. Heavy metal contamination in soil and water has become a global problem that is leading to loss in crop yield and hazardous effect on human health when these metals enter the food chain (Sankar ganesh et al .,2006 b). Among these heavy metals, Chromium merits a special reference for its toxic potential. It is used in a variety of industries such as leather processing and finishing, the production of refractory steel, drilling muds, electroplating cleaning agents, catalytic manufacturing and the production of chromic acid and specialty chemicals (Sankar ganesh et al., 2008). The higher amount of unused chromium is disposed from various industries such as steel works, electroplating, leather tanning and chemical manufacturing. Among them, tannery industry is one of the oldest industries in India. India is the largest market for hide and skin. Out of the total industrial used of Cr, 40% of Cr is used in leather processing industry and released to the environment.

Majority of tanneries in India are engaged in chrome tanning processes and they use nearly 40,000 tonnes of basic chromium every year, they are releasing 75,000 m^2 / day of liquid effluent (Sahasraraman and Bulijan.,2000). Only a fraction of chromium is absorbed in the tanning process and the remaining major part of chromium discharged through the effluent. It has been reported that these industries release 2,000 – 3,200 tonnes of Cr into the environment through effluent annually (Sankar ganesh.,2009). The concentration of Cr in the tannery waste is about 20.000 ppm, about 1800 ppm in the sludges and 200 ppm in the composite effluent. So,the present study, seven Paddy varieties was selected as test plant to investigate the impact of exogenous application of various levels of chromium on its growth metabolism.

2. MATERIALS AND METHODS

Seven varieties of paddy (*Oryza sativa* L. var. ADT 36, ADT 45, ASD 16, CO 33, CO 43, CO 47, and TKM 9) were obtained from Tamil Nadu Rice Research Institute, Regional Research Station of Tamil Nadu Agricultural University, Aduthurai, Thanjavur district of Tamil Nadu, India. The healthy seeds of paddy variety were surface sterilized with 0.1 per cent mercuric chloride for 2 min and washed thoroughly with tap water and then with distilled water. The sterilized seeds of ten varieties of paddy were arranged equispacially in plastic trays lined with filter paper. They were irrigated uniformly with equal volume of different concentrations (2.5, 5, 10, 25, 50, 75, 100, 200 and 300 mg/l) of chromium solution. The seeds irrigated with distilled water were maintained as control. They were allowed to grow for a week. Three replications were maintained for this varietal screening experiment.

2.1. Germination percentage

The number of seeds germinated in each treatment was counted on each and every day upto 7th day after sowing. The total germination percentage was calculated using the following formula:

$$\text{Germination percentage} = \frac{\text{Total number of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

2.2. Seedling length (cm/seedling)

Twenty seedlings were randomly selected on 7th day from each treatment to record the seedling growth. The growth of the ten varieties of paddy seedlings was measured by using a centimetre scale and the values were recorded.

2.3. Dry weight (g/seedling)

Twenty seedlings were taken and kept in a hot air oven at 80 °C for 24 hrs. Then, the samples were kept in desiccators and the dry weight was taken by using an electrical single pan balance. The average was expressed in g/seedling. On the basis of the data obtained from varietal screening experiments, the variety ASD 16 was identified as tolerant when compared with other varieties tested. So, the tolerant variety ASD 16 was taken for further experiments.

2.4. Accumulation of Chromium

In order to evaluate the amount of chromium accumulation 0.05 g dry tissue were poured in a 25 ml Erlenmeyer flask. Then 3 ml of concentrated nitric acid were added to the tissues and were placed for 72-48 hours in vitro and then they were heated slowly for 2-3 hours, until finally a clear solution was obtained. Due to oxidation of the carbonic and organic nitrogen components in the form of CO2 and NO2 and other nitrogen gases exit the tissue environment, the mineral elements of the plant remained in the wet ash plant. After cooling, the capacity of the remained solution was increased to 25 ml by distilled water and then it was filtered by filter paper and from this solution filtered, was used to measure chromium in the plant tissues by the atomic absorption spectrophotometer system (Piper, 1966)

3. RESULTS AND DISCUSSION

Germination, the critical phase in the life cycle of a crop plant, is subjected to numerous environmental stresses. Any disturbance in the environment in which the seed germinates affects the germination and ultimately the growth, dry weight and yield of crop (Dixit *et al.,* 1986). Seeds showing adverse effects for water pollution have produced plants manifesting inhibition in their metabolic activities. The presence of pollutants in air, water and soil affected the morphological, physiological, biochemical processes, mineral uptake, assimilation, biosynthesis and translocation leading to growth reduction and productivity losses in plants. Over or under supply of one element might cause adverse effect on the uptake of other nutrients, which causes the reduction in plant growth and development (Srivastava, 1991).

In this experiment, seven varieties (ADT 36, , ADT 45, ASD 16, CO 33, CO 43, CO 47 and TKM 9) of paddy were screened for their tolerance to chromium pollution in laboratory conditions. On the seventh day after sowing, the morphological parameters such as germination percentage, growth and dry weight of ten varieties of paddy seedlings were taken into consideration for this varietal screening experiment. Since seed germination is the first physiological process affected by chromium, the ability of a seed to germinate in a medium containing chromium would be an indicative of its level of tolerance to this metal (Peralta *et al.,* 2001). On the basis of germination behaviour, the variety that performed well was regarded as chromium tolerant and the variety performed poorly as chromium sensitive. From this study all the parameters such as germination percentage, seedling length and dry weight of paddy varieties were gradually decreased with the increase in chromium concentrations. The reduction in germination percentage, seedling length and dry weight of paddy seedlings 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; Subramani *et al.,* 1999). It is well established that the germinating seeds absorb considerable amount of water to attain their critical level prior to germination. The salt content outside the seed is known to act as a limiting factor and it might be responsible for the delay in germination (Adriano *et al.,* 1973). This view is also supported by Bishnoi *et al.* (1993a); Joshi *et al.* (1999); Tripathi and Smith (2000); Zeid (2001); Han *et al.* (2004) and Panda and Choudhury (2005b).

Growth and productivity in a crop variety depend on carbon assimilation, nitrogen assimilation and nutrition uptake. Among the seven varieties of paddy, ASD 16 was tolerant to chromium when compared to all other varieties and ADT 45 was sensitive to chromium treatment. The growth response of ADT 45 variety showed their inability to cope up with the toxic levels of chromium. All other varieties were intermediate in their growth response to chromium. The inhibition in growth and yield parameters was probably due to the interference of heavy metals with the respiratory activity of plant (Dua and Sawhney, 1991; Jain *et al.,* 2000).

Chromium uptake by plants is mainly non-specific, probably as a result of uptake of essential nutrients and water (Ghosh and Singh, 2005). Chromium uptake and translocation in different plant parts were variable with respect to genus and species. A higher accumulation of chromium content was observed in the roots and lower accumulation of chromium was observed in shoots of paddy varieties. Among treatments, a higher chromium content of paddy was observed in 200 mg/l chromium concentrations when compared to other chromium treatments. No chromium accumulation was recorded in control plants. Higher chromium was accumulated in the variety ADT-45.Similarly lower chromium was accumulated in the variety ASD-16. Similar observations of chromium accumulation in various plants were recorded (Satyakala and Jamil, 1992; Zayed *et al.,* 1998; Qian *et al.,* 1999; Castilhos *et al.,* 2001; Dirilgen and Dogan, 2002; Dahiya *et al.,* 2003; Chandra and Kulshreshtha, 2004; Rai *et al.,* 1995; 2004). The roots accumulated more chromium than the shoots in all the treatments. It may also due to the roots had high cation exchange capacity that can greatly reduce the movement of heavy metal towards leaves (Nicolo *et al.,* 1995; Kadlec and Knight, 1996), the availability and limited mobility of metals within root system is one of the reasons for the higher accumulation of metals in roots (Deng *et al.,* 2004), most of the absorbed chromium was retained in vacuoles of root cells in soluble form and 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.,* 2004).

4. CONCLUSION

Toxicity effects of chromium on growth and development of plants including inhibition of germination process decrease of growth and biomass of plant. The aim of this research is to study the accumulation of Cr and its effect on the Germination and growth of some paddy varieties. Thus, the varieties such as ADT-43, ADT-45, IR-50, TKM-9, CO-33, ASD-16 and CO-43 are grown in petriplates treated with different concentrations of Chromium (0, 5, 10, 25, 50, 100, and 200 mg/L). After one week exposure the seedlings were removed and morphophysiological parameters like germination percentage, seedling length and dry weight of paddy varieties and accumulation of Cr were determined. The results indicated that the concentrations more than 100 mg/L chromium cause the reduction of morphophysiological parameters in the treatments rather than control and Cr addition in the cultures caused enhancement of chromium content in roots and shoots of plant seedlings. It was also noted that accumulation of chromium in the roots was much higher than the shoots of the paddy seedlings under treatment.

Table 1. Seed germination percentage of seven varieties of paddy (*Oryza sativa* L.) as influenced by different concentrations of chromium.

Chromium concentrations (mg/l)	Name of the paddy varieties						
	ADT 36	**ADT 45**	**ASD 16**	**CO 33**	**CO 43**	**CO 47**	**TKM 9**
Control	98.0	96.0	100.0	98.0	98.0	96.0	98.0
2.5	94.0 (-4.08)	90.0 (-6.25)	98.0 (-2.00)	92.0 (-6.12)	94.0 (-4.08)	94.0 (-2.08)	94.0 (-4.08)
5	88.0 (-10.20)	84.0 (-12.50)	96.0 (-4.00)	86.0 (-12.24)	88.0 (-10.20)	90.0 (-12.50)	90.0 (-8.16)
10	82.0 (-16.32)	80.0 (16.66)	92.0 (-8.00)	82.0 (-16.32)	82.0 (-16.32)	82.0 (-14.58)	84.0 (-14.28)
25	80.0 (-18.36)	76.0 (-20.83)	88.0 (-12.00)	80.0 (-18.36)	80.0 (-18.36)	78.0 (-18.75)	82.0 (-16.32)
50	72.0 (-26.53)	70.0 (-27.08)	82.0 (-18.00)	74.0 (-22.44)	76.0 (-22.44)	72.0 (-25.00)	74.0 (-24.48)
75	68.0 (-30.61)	64.0 (-33.3)	76.0 (-24.00)	70.0 (-28.57)	70.0 (-28.57)	66.0 (-31.25)	68.0 (-30.61)
100	58.0 (-40.81)	50.0 (-47.91)	62.0 (-38.00)	56.0 (-42.85)	58.0 (-40.81)	56.0 (-41.66)	58.0 (-40.81)
200	52.0 (-46.93)	42.0 (-56.25)	60.0 (-40.00)	48.0 (-51.02)	48.0 (-51.20)	50.0 (-47.91)	52.0 (-46.93)

Percentage over control values are given in the parentheses.

Table 2. Seedling length (cm/seedling) of seven varieties of paddy (*Oryza sativa* L.) as influenced by different concentrations of chromium.

Chromium concentrations (mg/l)	Name of the paddy varieties						
	ADT 36	**ADT 42**	**ASD 16**	**CO 33**	**CO 43**	**CO 47**	**TKM 9**
Control	21.8	20.6	24.2	21.2	20.6	20.8	22.8
2.5	18.9 (-13.30)	18.8 (-8.73)	23.1 (-4.54)	18.7 (-11.79)	19.2 (-6.79)	19.4 (-6.73)	20.6 (-9.64)
5	17.3 (-20.64)	17.0 (-17.47)	21.4 (-11.57)	16.8 (-20.75)	17.2 (-16.50)	17.6 (-15.38)	18.2 (-20.17)
10	15.9 (-27.06)	15.8 (-23.30)	19.6 (-19.00)	16.0 (-24.52)	16.4 (-20.38)	16.5 (-20.67)	17.0 (-25.43)
25	15.0 (-31.19)	15.2 (-26.21)	18.0 (-25.61)	15.2 (-28.30)	15.0 (-27.18)	15.0 (-27.88)	16.2 (-28.94)
50	13.6 (-37.61)	13.7 (-33.49)	16.8 (-30.57)	14.4 (-32.07)	14.3 (-30.58)	14.6 (-29.80)	14.9 (-34.64)
75	12.0 (-44.95)	12.2 (-40.77)	14.4 (-40.49)	13.0 (-38.67)	13.1 (-36.40)	13.3 (-36.05)	13.0 (-42.98)
100	9.8 (-55.04)	10.2 (-50.48)	12.8 (-47.10)	11.0 (-48.11)	10.8 (-48.11)	10.6 (-49.03)	10.8 (-52.63)
200	7.8 (-64.22)	7.9 (-61.65)	9.8 (-59.50)	7.8 (-63.20)	7.5 (-63.59)	7.6 (-63.46)	7.7 (-66.22)

Percentage over control values are given in the parentheses.

Table 3. Seedling dry weight (g/seedling) of seven varieties of paddy (*Oryza sativa* L.) as influenced by different concentrations of chromium.

Chromium concentrations (mg/l)	Name of the paddy varieties						
	ADT 36	ADT 42	ASD 16	CO 33	CO 43	CO 47	TKM 9
Control	0.122	0.123	0.159	0.120	0.112	0.140	0.152
2.5	0.108 (-12.29)	0.116 (-5.69)	0.152 (-4.40)	0.109 (-9.16)	0.106 (-5.35)	0.127 (-9.28)	0.144 (-5.26)
5	0.099 (-18.85)	0.098 (-20.32)	0.143 (-10.06)	0.105 (-12.50)	0.098 (-12.50)	0.109 (-22.14)	0.133 (-12.50)
10	0.090 (-26.22)	0.089 (-27.64)	0.134 (-15.72)	0.087 (-27.50)	0.084 (-25.00)	0.102 (-27.14)	0.122 (-19.73)
25	0.073 (-40.16)	0.080 (-34.95)	0.126 (-20.75)	0.072 (-40.0)	0.072 (-35.71)	0.098 (-30.00)	0.107 (-29.60)
50	0.066 (-45.90)	0.071 (-42.27)	0.104 (-33.96)	0.065 (-45.83)	0.067 (-40.17)	0.072 (-48.57)	0.096 (-36.84)
75	0.057 (-53.27)	0.062 (-49.59)	0.096 (-39.62)	0.060 (-50.00)	0.057 (-49.10)	0.065 (-53.57)	0.080 (-47.36)
100	0.050 (-59.01)	0.049 (-60.16)	0.087 (-45.28)	0.057 (-52.50)	0.056 (-50.00)	0.058 (-58.57)	0.072 (-52.63)
200	0.049 (-59.83)	0.044 (-62.60)	0.069 (-56.60)	0.054 (-55.00)	0.049 (-52.50)	0.052 (-68.5)	0.066 (-56.57)

Percentage over control values are given in the parentheses.

Table 4. Accumulation of chromium (µg/g) in seven varieties of paddy (*Oryza sativa* L.) as influenced by different concentrations of chromium.

Chromium concentrations (mg/l)	Name of the paddy varieties						
	ADT 36	ADT 42	ASD 16	CO 33	CO 43	CO 47	TKM 9
Control	-	-	-	-	-	-	-
2.5	20.0 ± 0.9	18.5 ± 0.8	10.5 ± 0.9	19.2 ± 0.8	18.3 ± 0.8	16.2 ± 0.8	18.6 ± 0.8
5	23.4 ± 1.0	19.9 ± 0.8	12.0 ± 1.0	21.0 ± 0.9	19.8 ± 0.9	18.4 ± 0.8	20.0 ± 0.8
10	25.3 ± 1.0	22.0 ± 0.9	16.5 ± 1.0	23.0 ± 0.9	22.0 ± 0.9	22.7 ± 0.9	23.0 ± 0.9
25	27.0 ± 1.0	24.5 ± 0.9	22.2 ± 1.0	25.3 ± 1.0	24.2 ± 1.0	24.6 ± 1.0	26.1 ± 1.0
50	28.2 ± 1.1	26.6 ± 1.0	24.0 ± 1.0	26.0 ± 1.1	26.4 ± 1.1	26.0 ± 1.1	27.0 ± 1.1
75	30.1 ± 1.2	28.8 ± 1.1	25.5 ± 1.2	27.9 ± 1.2	28.8 ± 1.3	29.0 ± 1.3	30.0 ± 1.2
100	32.0 ± 1.3	34.5 ± 1.1	28.2 ± 1.2	30.0 ± 1.2	32.1 ± 1.3	33.0 ± 1.3	35.5 ± 1.3
200	33.0 ± 1.4	38.4 ± 0.9	30.0 ± 1.2	32.5 ± 1.2	34.0 ± 1.2	36.0 ± 1.3	38.8 ± 1.3

± Standard deviation.

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