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Toxicity of cadmium on the growth and yield of *Solanum melongena* L.

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Abstract: *Heavy metal cadmium is biomagnified through food chain and causes Itai-Itai disease in human. The present investigation reports the results of the effect of cadmium on seed germination, germination relative index (G.R.I.), seedling growth, chlorophyll stability index (CSI) and yield of Solanum melongena L. cv. Pusa uttam. Effect of different concentrations of heavy metal cadmium ($CdCl_2$) in Hoagland's nutrient solution (10^{-2} M, 10^{-4} M, 10^{-5} M and 10^{-8} M) were employed for all seedling and physiological parameters of brinjal. Cadmium showed toxic effects at high concentrations 10^{-2} M but promotory at lower concentration (10^{-8} M) with regard to growth and yield.*

Key words: *Cadmium, Solanum melongena L., Germination relative index, Chlorophyll stability index*

Introduction

Cadmium discovered by Strohmeyer in 1817 is a soft, silver, hazardous, heavy metal and occurs naturally in earth's crust. It is placed in II-B group and period 5th of periodic table. Cadmium is a biologically non-essential metal. It is toxic to both plants and human beings (Shukla *et al.,* 2007). It cause Itai-Itai disease, anemia, mainly in women over forty and induce hormosis (low dose stimulation and high dose inhibition) in plant (Calabrese and Baldwin, 1997, 1999). Cadmium toxicity is an important growth limiting factor for plants (Akinola and Ekiyoyo, 2006; Mohan and Hosetti, 2006). The problem of heavy metal is accentuated by heavy application of phosphate fertilizers (rock phosphate). The initial site of cadmium uptake is root cap and mucilaginous secretion absorbed in cortical cell wall, closest vacuole or loaded into xylem for transport into leaves.

Inhibiting effect of cadmium on seed germination (Lata, 1988; Munzuroglu and Zengin, 2006), plant growth (Greger and Ogren, 1991), photosynthesis, enzymes, stomatal function and plant metabolism (Siedleka and Kurpa, 1997) were observed. Cadmium adversely affected microbial population, size diversity, and other microbial process such as N_2 fixation *etc.* (Giller *et al.*, 1998). Barman *et al.* (1999) studied the accumulation of heavy metals in vegetables, pulse and wheat grown in flyash amended soil and availability of cadmium to plants in presence of organic acid in soil (Nigam *et al.*, 2004). John *et al.* (2007) studied the antioxidative response of *Lemna polyrrhiza* L. to Cd stress and impact of Cd and Pb on *Catharandhus roseus* (Pandey *et al.*, 2007). Organic acids increases metal uptake by plants and play an important role in transport, sequestration and tolerance of metals (Hooda, 2007). There seems to be an urgent need to make a detailed study on role of cadmium on plant growth as metal toxicity is one of the major constraints that limits plant growth and productivity in general. The aim of present investigation is to evaluate the effect caused by cadmium on germination percentage, GRI, seedling growth, chlorophyll content, chlorophyll stability index, growth and yield of *Solanum melongena* L.

Materials and Methods

Healthy uniform seeds of *Solanum melongena* L. cv. Pusa uttam were procured from IARI, New Delhi and were sterilized with 0.1% $HgCl_2$ solution for 20 minutes and then washed thrice with distilled water (Samantaray and Deo, 2004). The $CdCl_2$ solution was prepared by dissolving it in Hoagland's nutrient solution in different concentrations *viz.*-10^{-2}M, 10^{-4}M, 10^{-5}M, 10^{-8}M and control. Seeds were imbibed for 24 hr in $CdCl_2$ solutions at room temperature (min 22.5°C and max 32.3°C) and relative humidity of (82.9%). Cadmium was supplied in the form of cadmium chloride (water-soluble). These were transferred to whatman no. 1 filter paper contained in 9 cm petriplate and polythene bags with 10 kgs. sandy loam soil, pH 7.5 in triplicate for germination and seedling growth during July 2004. The seedlings were dissected into radicle and plumule for dry weight and kept at 48-60°C in oven. Data on the germination percentage and germination relative index (GRI) was observed on 3rd, 5th, 7th and 10th days after sowing (DAS). GRI was calculated as per the following equation-

$$GRI = (S)\ Xn\ (K - n),$$

Where Xn = number of germinated seed on nth day, K= no. of counts and n = number of days. Phytotoxicity percentage was measured as suggested by Chou and Mullar (1972).

Chlorophyll (chl.) was estimated by Bausch and Lamb spectrophotometer (Spectronic-20) at absorbance 625, 644 and 662 nm respectively by following the method of Smith and Benitez (1955). Chlorophyll stability index (CSI) was calculated by the following formula-

$$CSI = \frac{\text{Chl. before Cd stress - Chl. at 30}^{th}\text{ day of stress}}{\text{Chl. before Cd stress}}$$

Table - 1: Effect of cadmium on the physiology of *Solanum melongena* L. cv. Pusa uttam

Particulars	DAS**	Control	10^{-2} M	10^{-4} M	10^{-5} M	10^{-8} M
Root length (cm)	3rd	-	-	-	-	-
	5th	4.022	3.466*	3.655*	3.822*	4.255
	7th	7.285	5.022*	5.88*	6.642*	7.3
	10th	7.525	5.514*	5.6*	6.875*	7.7
Shoot length (cm)	5th	-	-	-	-	-
	7th	3.933	3*	3.42*	3.42*	4.4
	10th	4.5	4.162*	4.312*	4.42	5.78
	5th	-	13.823968	9.1248135	4.97265	-5.79313
	7th	-	31.20547	19.45205	9.01369	-2.53424
	10th	-	28.38961	27.27272	13.74025	-1.62337
Phytotoxicity percentage of shoot length	7th	-	31.81818	22.27272	18.45454	-12.1163
	10th	-	27.99307	25.39792	23.52941	-3.4948
Lateral root plant^{-1}	7th	4.5714	4.5714*	4.5714*	4.5714*	6.857
	10th	5	5*	5*	5*	8.888
No. of leaves plant^{-1}	30th	4.16	3*	3.3*	4	4.25
	45th	4.18	3.12*	3.5*	3.66	4.35
	60th	8.81	5.522*	5.875*	7.98	9.1
	75th	9	7.4*	8*	8.2	10.5
	90th	11.66	8.2*	8.76	10.54	12.0112
	105th	7.0212	5.11*	6.214	6.78	8.224
No. of branches plant^{-1}	60th	1.6	1.2*	1.3*	1.4	1.621
	90th	2.2	1.42*	1.53*	1.68*	2.2
	120th	2.5	1.52*	1.767	1.798	2.3
Days to 50% flowering		77.33	80.66	78.33	77.66	76.66
No. of fruit plant^{-1}		2.333	1.2*	1.4*	1.6*	1.8*
Fresh weight of fruit plant^{-1} (g)		137.4	111*	124*	130.11	130.4*
No. of seed fruit^{-1}		960	540*	740*	802*	890*
1000 seeds weight (g)		1.4168	0.6512*	0.25295*	0.66212*	0.69231*
Harvest index plant^{-1}		18.05339	6.71743*	7.54312*	7.61302*	9.09904*

CD (Critical difference), *- Significant at 5% level; DAS** = Days after sowing

Table - 2: Effect of cadmium chloride ($CdCl_2$) on chlorophyll contents (mg g^{-1} fresh weight) of *Solanum melongena* L. cv. Pusa uttam

Particulars	DAS**	Conc.	P- chl.	Chl. *a*	Chl. *b*	Total chl.	Chl. *a* ÷ *b*
	30th	Control	1.609	0.414	0.110	0.524	3.76
		10^{-2} M	1.433*	0.291*	0.070*	0.362*	4.11*
		10^{-4} M	1.460*	0.321*	0.075*	0.397*	4.23*
		10^{-5} M	1.501*	0.347*	0.098*	0.446*	3.52*
		10^{-8} M	1.541*	0.372*	0.107	0.479*	3.48
$CdCl_2$	60th	Control	0.689	0.192	0.051	0.243	3.78
		10^{-2} M	0.420*	0.128*	0.030*	0.137*	4.25*
		10^{-4} M	0.507*	0.142*	0.039*	0.181*	3.59*
		10^{-5} M	0.553*	0.156*	0.043	0.199*	3.59*
		10^{-8} M	0.619*	0.178*	0.047	0.262*	3.80
	90th	Control	0.563	0.154	0.049	0.204	3.19
		10^{-2} M	0.366*	0.085*	0.235*	0.109*	0.365*
		10^{-4} M	0.479*	0.120*	0.031*	0.151*	3.89*
		10^{-5} M	0.522*	0.141*	0.039*	0.181*	3.59*
		10^{-8} M	0.540*	0.150*	0.040*	0.197*	3.72

*LSD = Least significant at 5%, DAS** = Days after sowing; P-chl = Proto- chlorophyll

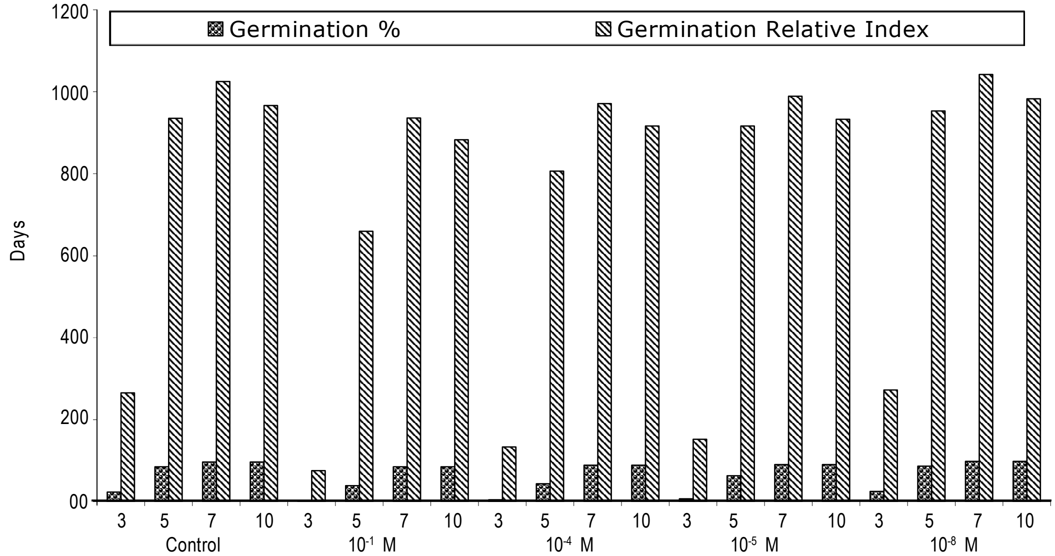

Fig. 1: Effect of cadmium on germination percentage and germination relative index on *Solanum melongena* L. cv. Pusa uttam

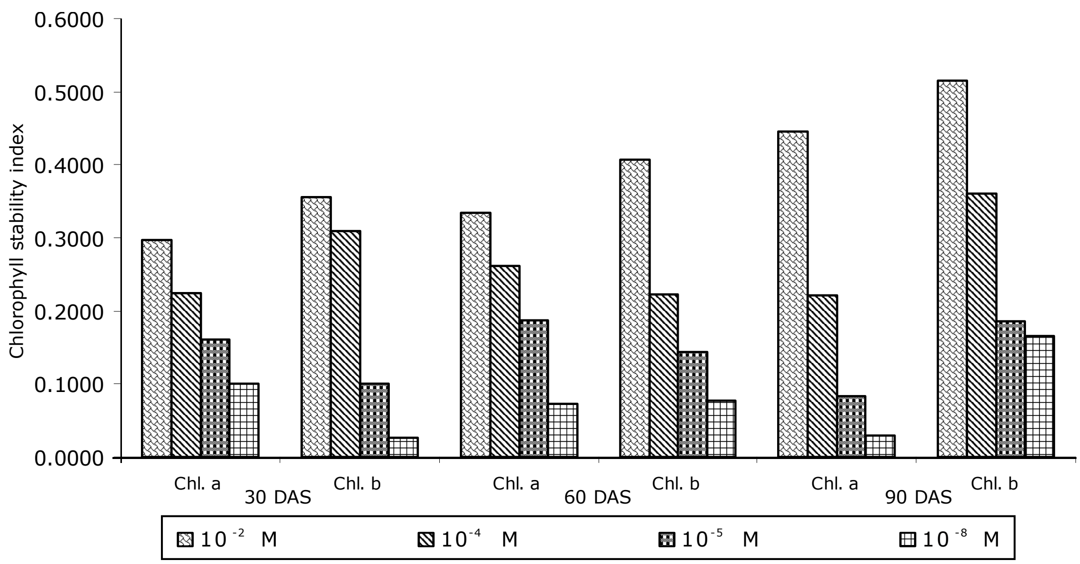

Fig. 2: Effect of cadmium on chlorophyll stability index (CSI) at 30, 60 and 90th days of *Solanum melongena* L. cv. Pusa uttam

The other attributes such as branches, leaves were recorded at 60th, 90th, 105th days and number of fruit, fresh weight of fruit, no. of seed berry/fruit^{-1}, 1000 seeds weight and harvest index were observed at harvest. The number of days from the date of sowing to the appearance of flowers in 50% plants were recorded. The data were analysed by analysis of variance (ANOVA) and significance was set LSD (least significant difference) at 5% level.

Results and Discussion

Germination percentage of *Solanum melongena* L. cv. Pusa uttam was studied in four concentration of $CdCl_2$ in Hoagland's nutrient solution (10^{-2} M, 10^{-4} M, 10^{-5} M and 10^{-8} M). It was observed that the seed initiated germination by bursting seed coat just after 48 hr in 10^{-2} M concentration (lethal) of cadmium while in other concentration seeds showed the beginning of germination on 3rd day. The data on germination relative index (GRI) observed is inversely proportional to the concentration of $CdCl_2$ over control. 10^{-2} M has significantly reduced the GRI however, 10^{-4} M and 10^{-5} M have moderate lethal effects, and 10^{-8} M (sub-lethal) concentration revealed Cd tolerant (Fig. 1). The negative value of phytotoxicity percentage (PP) indicate the stimulatory effects, while the positive value showed significant reduction (Table 1).

The present investigation elucidated that biometric attributes such as length of radicle and plumule, number of lateral roots, number of branches, leaves, chlorophyll contents and CSI (chlorophyll stability index), days to 50% flowering, total number of fruits plant^{-1}, number of seeds, fresh weight of fruit, 1000 seeds weight of *Solanum melongena* L. cv. Pusa uttam (Egg plant) were affected by cadmium. The germination percentage, root and shoot length and dry weight of seedlings significantly decreased with increasing concentration of $CdCl_2$. Cd, inhibits the lateral roots in higher concentration due to its toxic effect. The weight of the seedling was correlated with the growth of the seedlings. This might be due to inert interaction of Cd on emergence of radicle in the laboratory conditions. Similar trends of results have been observed in GRI (Table 1). Proto-chlorophyll, Chl. *a* and Chl. *b* and chlorophyll stability index (CSI) of leaves declined significantly with increasing concentration of $CdCl_2$ (Fig. 2). Early senescence in leaf and flowering with low yield were evident with increasing concentration of cadmium chloride. Number of branches, leaves plant^{-1}, number of fruit plant^{-1} also decreased with the increased Cd concentration. Days to 50% flowering is slightly advanced in 10^{-8} M and late in 10^{-2} M concentration of cadmium. Similar trends of results have also been observed in number of seed fruit^{-1}, fresh weight and 1000 seeds weight of fruit and harvest index (HI).

The results revealed that cadmium, inhibits the germination percentage, germination relative index (GRI) and seedling growth. Data on the seed germination of *Solanum melongena* L. cv. Pusa uttam revealed that higher concentration of Cd significantly reduced the seed germination while lower concentration showed the elevating effects over the control. Inhibition of seed germination at higher concentration may be due to the activity of hydrolytic enzymes required at the time of germination. Thus germination and subsequent seedling growth were also inhibited. Similar results were also observed by Jerome and Ferguson (1972) and Lata (1988). According to GRI plants are categorized into three main groups *viz.,* cadmium tolerant (10^{-8} M), moderately sensitive (10^{-4} M, 10^{-5} M) and highly sensitive (10^{-2} M). More stress has been observed in 10^{-2}M concentration while less in 10^{-8} M concentration. The results are in the conformity with Sharma (1983). Rothenberger and Galitz (1977) discussed the toxic effect of Cd, Zn, Pb and Mo on germination and seedling growth of selected grasses and the effect of cadmium on seed germination. Differential effect of Cd and Hg on growth and metabolism of *Solanum melongena* L. were observed by Neelima and Reddy (2003). An interesting feature of the results is that at lower concentration the seedling growth is more than control. Similar observations were also reported (Lata, 1988). Higher concentration of cadmium reduces shoot length, leaves, branching and alteration in chloroplast ultra structure thereby lowering of photosynthetic activity (Mehindirata *et al.,* 2000). Khan and Khan (1983) reported the influence of Pb and Cd on the growth and nutrient concentration of tomato (*Lycopersicum esculentum*) and egg plant (*Solanum melongena* L.).

Results on the progressive decrease in chlorophyll content revealed that Cd impairs the Proto-chl., Chl. *a*, Chl. *b* and total chlorophyll sequentially on 30th, 45th and 90th DAS as the concentration of metal increases. While Chl. *a* and Chl. *b* showed maximum at 10^{-2} M on 30th and 60th DAS in consecutive years. Chlorophyll degradation includes inversible to protein conformation by forming metal thiolate bonds. The basis of these disfunctions include inversible to protein conformation by forming metal thiolate bonds (Dafre *et al*., 1996) and alteration of cell wall and membrane permeability by binding to nucleophilic groups (Ramos *et al.*, 2002). Iannelli *et al*. (2002) studied that Cd induced antioxidant response in all plant organs. Chlorosis in present investigation may be due to higherconcentration of cadmium interference with Mg^+. It was also assumed that Cd induced the significant chlorophyll loss *i.e.* visible chlorosis at higher concentrations, either by the formation of active oxygen species or by interfering with redox status. Similar observations are reported by Baryala *et al.* (2001), Schutzendubel *et al.* (2001). Chlorophyll contents as well as chlorophyll stability index decreased in different concentration of Cd. However, the most stress 10^{-2} M concentration showed higher CSI value in *S. melongena* L. A high correlation between CSI and field drought tolerance has been suggested by Murthy and Majumdar (1962). Therefore CSI could be a reliable index for assessing the degree of stress (Cd) tolerance of crop plants.

At 10^{-2} M concentration of cadmium affected most drastically to the number of leaves, branches, fruit and fruit yield of egg plant while increasing conc. of cadmium. Similar observations have been reported by Mehindirata *et al.* (2000). Flowering showed that appearance of 50% flowering was slightly advanced under more Cd over control. It might be due to the enhanced formation of florigin harmone which depicts early flowering in treated plant as compared to control. The advancement of flowering could be related with the accumulation of carbohydrates due to increased photosynthetic efficiency. Physiology of seed and fruit yield has been affected by cadmium in terms of decrease in number of seed/fruit, weight of 1000 seeds, number and fresh weight of fruit plant^{-1}. Number of seed fruit^{-1}, 1000 seeds weight, number of fruit/berry plant^{-1} and fruit yield plant^{-1} showed a significant prohibition at higher concentration(10^{-2} M) of $CdCl_2$. While in lower concentration (10^{-8} M) a significant stimulatory observations are in connumeration of Homna and Hirta (1974), Masih *et al.* (2004).

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