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Changes in growth, photosynthetic responses and biochemical contents of carrot plants under cadmium toxicity

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SUMMARY

The effect of increasing concentrations (10, 30 and 50mg kg^{-1}) of soil cadmium on growth and biochemical contents in carrot (*Daucus carota* L.) plants were analysed on two different sampling *viz.*, 30th and 45th days. Photosynthetic rate and stomatal conductance were measured on 45th sampling days only. Control plants were maintained separately. The inner surface of pots was lined with a polythene sheet. Each pot contained 3kg of air dried soil. Six seeds were sown in each pot. All pots were watered to field capacity daily. Plants were thinned to a maximum of three per pots, after a week of germination. Cadmium at all levels (10,30 and 50mg kg^{-1}) tested, decreased the growth parameters such as root and shoot length, number of leaf, total leaf area, photosynthetic responses such as photosynthetic rate and stomatal conductance and biochemical constituents such as total chlorophyll, carotenoid and total sugar contents of carrot plants compared to untreated plants.

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Key words : Cadmium, Carrot, Growth, Photosynthesis, Biochemical changes

Heavy metals are important environmental pollutants particularly in areas where there is a high anthropogenic pressure, but they also occur naturally (Alloway,1995a; Sanità di Toppi and Gabbrielli, 1999). Anthropogenic cadmium contamination often results from mining or smelting of metal ores, but cadmium is also released into the environment by power stations, heating systems, waste incinerators, urban traffic, cement factories and as a by-product of phosphate fertilizers. Use of sewage sludges as fertilizers has further contributed to a significant contamination of agricultural soils. In areas with low anthropogenic pressure, natural high concentrations are observed, for example in soils formed on metal rich rocks, such as serpentine soils that release cadmium as a result of rock mineralization processes (Alloway, 1995a; Sanità di Toppi and Gabbrielli, 1999; Adriano, 2001). Apart from some emission into the atmosphere in the form of dust particles or vapors, heavy metals stay largely in the aquatic and soil phases of the planet.

Cadmium is one of the toxic heavy metal which has many deleterious biological aspects (Nriagu, 1981), and it enters the biosphere through various industrial waste products, certain plants can accumulate heavy metals in their tissues. Uptake is generally increased in plants that are grown in areas with increased soil concentrations of metals. Many people could be at risk of adverse health effects from consuming common garden vegetables cultivated in contaminated soil. Often the condition of garden soil is unknown or undocumented; therefore, exposure to toxic levels can occur. Xu and Thornton (1985) suggested that there are health risks from consuming vegetables with elevated heavy metal concentrations. The populations most affected by heavy metal toxicity are pregnant women or very young children (Boon and Soltanpour 1992). In the present investigation extent of changes in growth parameters such as, root and shoot length, number of leaves and leaf area, photosynthetic rate, stomatal conductance and biochemical constituents such as, total chlorophyll, carotinoids, and total sugar contents in carrot plants due to cadmium toxicity were

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workedout.

MATERIALS AND METHODS

The certified seeds of carrot (*Daucus carota* L.) were obtained from Tamilnadu Agriculture University (TNAU), Agricultural Research Station, Paramakudi, Ramanathapuram district (TN), India. Seeds with uniform size, colour and weight were chosen for the experimental purpose. The soil used in the experiment was sandy loam in nature and pH of the soils was 7.2. It contains major nutrients of 118kg available N, 88kg P and 106kg k/ha and micronutrients of 21.89mg available Cu, 219.11mg Fe, 168mg Mn and 28.13mg Zn/kg, cadmium was not available in this experimental soil. The cadmium chloride (Cd Cl_2 ½ H_2O) was used as cadmium source.

The pot culture experiments were conducted in Botanical Garden, Department of Botany, Annamalai University, during the period of June to March-2008. Carrot plants were grown in pots containing untreated soil (Control) and soil mixed with various levels of cadmium (*viz.*, 10, 30 and 50 mg kg^{-1}). The inner surfaces of pots were lined with a polythene sheet. Each pot contained 3kg of air dried soil. Six seeds were sown in each pot. All pots were watered to field capacity daily. Plants were thinned to a maximum of three per pots, after a week of germination. Each treatment including the control was replicated five times. Data points in the tables and figures represent the means, with all deviation bars shown (±1 standard deviations of mean). Both the mean and standard deviation were performed where appropriate using the statistical package on Microsoft_ Excel Version 2003.

The plant samples were collected on 30th and 45th days after sowing. Three plants from each replicates of pot was analysed for the various growth parameter such as root and shoot length, number of leaf and leaf area. The leaf area was calculated by measuring the length and width and multiplied by a correlation factor (0.69), derived from the method of Kalra and Dhiman (1977). The photosynthetic rate and stomatal conductance were measured by using infrared gas analyzer (Li Cor 6200 portable infrared gas analyzer, Li Cor Inc, USA). Leaves as treated and control plants were used for the estimation of total chlorophyll as per Arnon (1949), carotenoids as per Kirk and Allen (1965), total sugar as per Nelson (1994).

RESULTS AND DISCUSSION

The findings of the present study as well as relevant discussion have been summarized under following heads:

Physio-chemical properties of the soil:

The pot cultures experiments were conducted in Botaniocal Garden, Department of Botany, Annamalai University. The soil condition was sandy loam in nature and pH, EC, organic carbon and available macro and micro nutrients are given in Table 1.

Growth:

The effect of cadmium on growth parameters such as root and shoot length of carrot plants are presented in

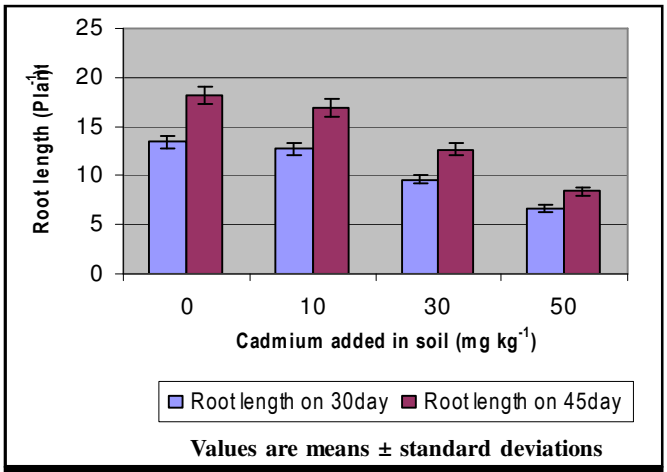

Fig. 1 : Cadmium toxicity in root length of *Daucus carota* L.

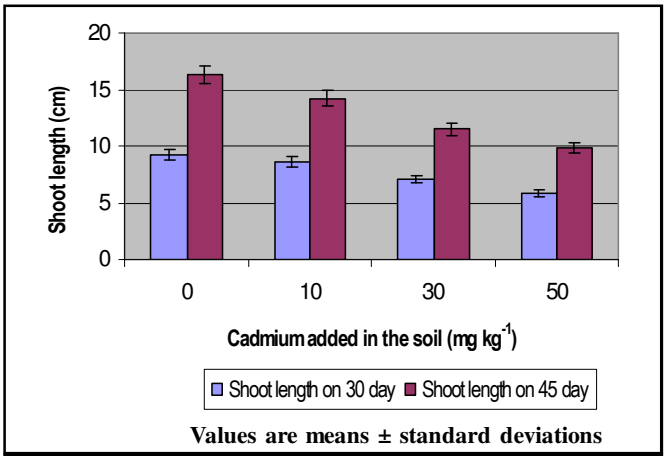

Fig. 2 : Cadmium toxicity in shroot length of *Daucus carota* L.

Table 1 : Physio-chemical properties of the experimental soil

Soil type	pH	EC	Moisture content	Organic carbon	Available(kg/h)			DTPA-TEA extractable (mg kg^{-1})				
					N	P	K	Cu	Fe	Mn	Zn	Cd
Sandy loam	7.2	0.4	20.10	0.56	118	88	106	21.89	219.11	168	28.13	-

Fig. 1 and 2. All growth parameters of cadmium treated plants (10, 30 and 50mg kg^{-1}) gradually decreased when compared to untreated plants. The maximum root (13.4, 18.2) and shoot (09.3, 16.3) length were recorded in control plants on 30th and 45th sampling days. The minimum value of all growth parameters were found in 50mg kg^{-1} of cadmium treated plants. Present results are in agreement with the findings of Juwarkar and Shende (1986), Yi and Ching (2003) and Xu *et al.* (2008) who also suggested that the higher concentrations of cadmium may inhibit root growth directly by inhibition of cell division or cell elongation or combination of both resulting in the limited exploration of the soil volume for uptake and translocation of nutrients and water and induced mineral deficiency. Schutzendubel *et al.* (2001) who reported that the cadmium also induced the generation of reactive oxygen species (ROS) and affected various toxicities in the cells, resulting in inhibition of plant growth and severely suppressed root elongation. The morphological and structural effects caused by metal toxicity in plants was due to decrease in root elongation, root tip damage, decrease in formation, suppression of elongation, growth rate of cells, affecting the ultracellular structure of meristamatic cells and inhibition of the size of plant cells and inter cellular spaces were also observed by Hagemeyer and Breckle (2002) and Marcnano *et al.* (2002).

Number of leaf and leaf area:

In the two sampling days, the minimum number of leaves (4.00, 6.10) and total leaf area (38.64, 59.70) were recorded in 50mg kg^{-1} of the cadmium treated soil and the maximum number of leaf and total leaf area were found in untreated plants Fig. 3 and 4. Present results are

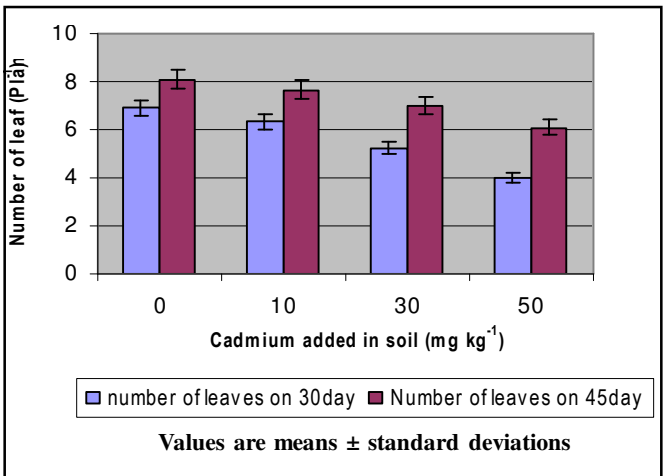

Fig. 3 : Cadmium toxicity in number of leave of *Daucus carota* L.

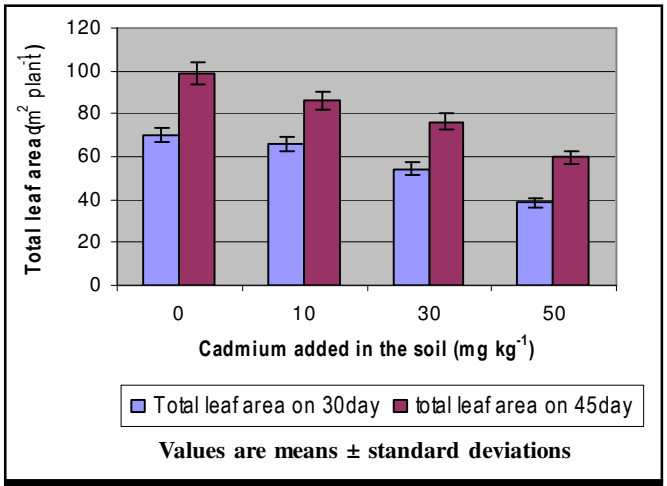

Fig. 4 : Cadmium toxicity in total leaf of *Daucus carota* L.

in consonance with the findings of Meiri and Poljakaff-mayber (1967) and Filippis and Ziegler (1993) who also suggested that the decrease in number of leaves and leaf area of plant at higher concentrations of cadmium might be due to reduce in cell size, decreased activities of many enzymes involved in the fixation of CO_2 changes in the thylakoid organization, reduction of chlorophyll contents and inhibition of photosynthesis activities.

Photosynthetic rate:

Results on the effect of cadmium on photosynthetic rate of leaves of carrot plants were recorded on 45th days only is presented in Fig. 8, increasing cadmium levels (10, 30 and 50mg kg^{-1}) in the soil, gradually reduced the photosynthetic rate of leaves of carrot plants. The maximum photosynthetic rate (1.467) was measured in leaves of control plants; the minimum photosynthetic rate (0.496) was measured in 50mg kg^{-1} levels of the soil. Present results are in agreement with the findings of Sakamoto and Murata (2001) who reported that the glycinebetaine -like macromolecule / membrane protecting effects inside and outside of cell could also contribute to its protective effects particularly in the case of cadmium stress affecting photosynthesis. Stoyanova and Chakalova (1990) established that cadmium, applied in toxic concentrations, disturbs the chloroplast envelope and the integrity of the membrane system and leads to increased plastoglobule number, changing the lipid composition and ratios of the main structural components of thylakoid membranes.

Stomatal conductance:

When compared to untreated plants, cadmium at all levels (10, 30 and 50mg kg^{-1}) tested, significantly reduced (0.493, 0.360 and 0.089) the stomatal conductance of

leaves of carrot plants Fig. 8. Several authors contributed various reasons for the reduced in stomatal conductance due to cadmium. Skorzynska-Polit and Baszynski (1997) who reported that the reduction in photosynthetic rate may be an indirect effect of cadmium through a decrease in chlorophyll content and stomatal conductance in bean plants. Cadmium may inhibit photosynthesis by increasing stomatal resistance of through such process as chlorophyll degradation and impairment PSII activity was suggested by Baszynski (1986).

Biochemical estimations:

Perusal of data in Fig. 5, 6 and 7, reveal that leaves of the plants raised in cadmium treated soils were poorer in total chlorophyll, carotenoids and total sugar contents

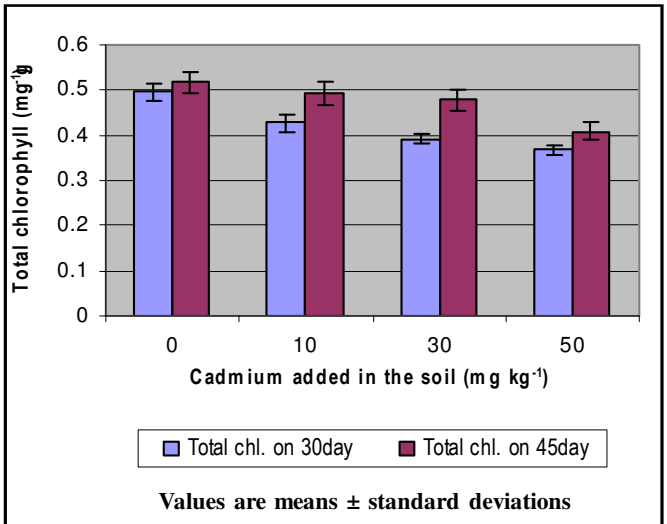

Fig. 5 : Cadmium toxicity in total chlorophyll of *Daucus carota* L.

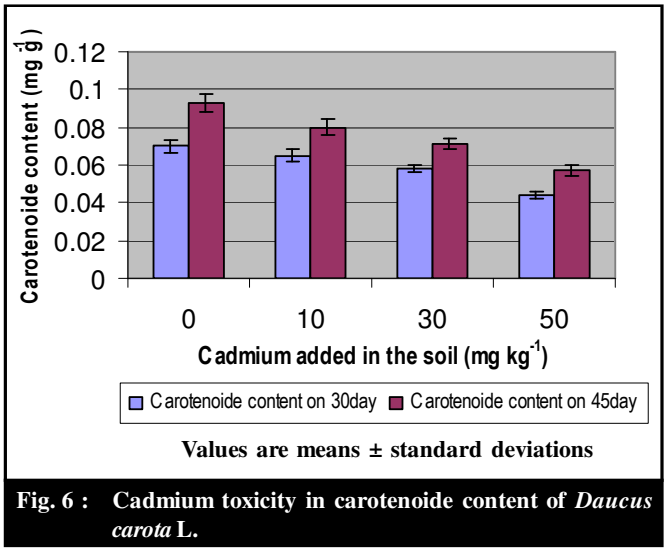

Fig. 6 : Cadmium toxicity in carotenoide content of *Daucus carota* L.

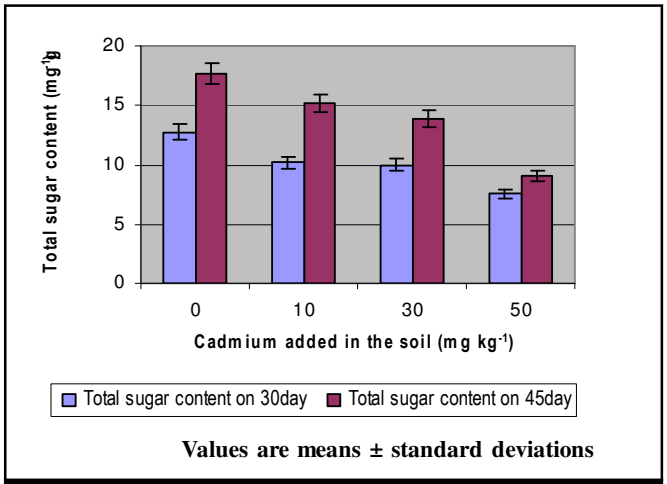

Fig. 7 : Cadmium toxicity in total sugar content of *Daucus carota* L.

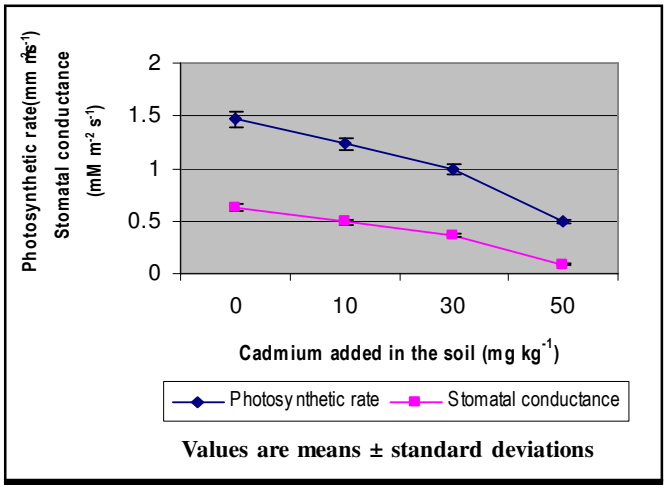

Fig. 8 : Cadmium toxicity in photosyntheticf rate and stomatal conductance of carrot plants

as compared to control plants in all the sampling days. Higher the cadmium contents lesser the values. The above results are in agreement with the findings of Van Assche and Clijsters (1990) who suggested that cadmium can alter chlorophyll biosynthesis by inhibiting the water-splitting enzyme located at the oxidizing site of photosystem II. The decline in the levels of chlorophyll and carotenoids may be due to the inhibition of cadmium at the protochlorophyllide stage interferes with the enzyme protechlorophyllide reductase in barley leaves observed by Stobart *et al.* (1985). The reduction of sugar content might be due to the imbalance which might evendully lead to deplection of carbohydrate reserves were recorded by Murata *et al.* (1969). Greger and Lindberg (1986) observed that the reduction of sugar content in the leaves by cadmium treatments implies the deranged metabolism and poor translocations of sugars and other metabolites

to the growing parts in the young sugar beet plant.

Conclusion:

The present investigation shows decrease in growth, photosynthetic responses and biochemical constituents of carrot plants, when compared to control plants. The loss of these may be due to inhibition of cell division, increasing stomatal resistance or through such process as chlorophyll degradation, impairment of PSII activity and Implies the deranged metabolism and poor translocations of sugar and other metabolites to the growing parts. So there was a consequents reduction in the growth of root and shoot length, number of leaves, leaf area, photosynthetic rate, stomatal conductance, chlorophyll, carotinoids and sugar content of carrot plants. The root length of cadmium treated carrot plants was higher than the shoot length.

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