INTRODUCTION
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Cadmium belongs to IIIb group of the periodic table, along with mercury and zinc. Of the three elements zinc is an essential element in plant metabolism. The physiological role of other two metals in plant metabolism is little understood and were reported as major environmental pollutants. Cadmium and mercury form the common pollutants in the environment and their occurrence in plants has been reported by many. The sources of cadmium include the agrochemicals, motor vehicle exhausts and industries. Although the Cd effects are better studied in aquatic organisms and animals, its toxic effects in higher plants are poorly understood. Hence the present investigation aims to study the cadmium toxicity on germination, growth and pigment synthesis in *Phaseolus aureus Roxb*.

Some practical implications of the present study include (1) studies on the effects of metals in plants may help in understanding the metal tolerance phenomenon in plants. The metal tolerant plants are useful in regenerating the toxic metalliferous wastes, mine relics and metal devastated environments. (2) The present study is also relevant to the pollution problem, since cadmium is one of the major pollutants in the environment.
Organisms have relied for their inorganic elements either from soil, water and atmosphere or from other forms of life already containing these elements. It is apparent from the current research that the list of elements which are essential and have a function in the organism may need a revision, since the heavy metals such as Pb, Hg, As, Cd etc., which are previously considered non-essential or ignored are commonly found in organisms. This may be because of their occurrence in all parts of the world, as pollutants in the environment.

It is well known that cadmium is a major environmental pollutant and is highly phytotoxic affecting the plant growth and yield (Haghiri 1973). It is present in air samples, road side soils, road side surface dust and water and it was found that total cadmium was associated with exchangeable fraction (Harrison et al. 1981). The sources of cadmium include agrochemicals, motor vehicles exhausts, especially automobiles (Khan 1981), smelters, industrial effluents (Seth and Pandey 1983) and in areas where oil is burned for heating purposes (Lagerwerff 1967). The cadmium aerosol settles out with dust or precipitation (Friberg et al. 1971), and contaminates the soils and plants.
It was reported that world production of Cd exceeds 15000 tonnes/year and increases 10% every year by mining. Plants growing on the mines, and mine relics have been known to accumulate several metals including Pb, Cd, and Ni. The metals so accumulated are hazardous to the other dependent organisms including human beings by consuming of such plants, even though the plants may not show visual symptoms of contamination. Hence the studies on the effect of cadmium on humans should be important since it is an accumulable element which in certain doses can be dangerous (Ribesovonas 1981).

Investigations on samples of wheat and its derivatives (bread etc.) for Pb and Cd pollution in U.S.A. have shown appreciable and continuous increase in the concentration of such elements from 1974 and the limits proposed by Food and Agriculture Organisation and World Health Organisation were exceeded in 1977 (Bolasoo et al. 1981). Soybean plants grown on sludge amended soil high in Cd content were analysed for cadmium and lead and fractionated to simulate industrial food processing. Of the fractions, oil retained least cadmium, which accumulated in the protein enriched fractions (Braude et al. 1980).
In an area of high Cd contamination Yamagata and Shigematsu (1970) reported an accumulation of 50 μg of Cd per gram dry weight in rice plants. The ions present in the atmosphere and soil may enter the plant by foliar absorption (Buchauer 1973) or by root system respectively (Lagerwerff and Specht 1970, Page et al. 1972, Haghl 1973, and Rolfe 1973).

Buchauer (1973) reported that Quercus rubra seedlings growing 1 km away from a zinc smelter accumulated Cd up to 38 μg/g in foliage by foliar absorption and 25 μg/g in stem tissues. Roots collected within 1 km of a zinc smelter, contain Cd up to 1750 μg/g. Cd concentrations in soil and vegetation have been shown to decrease with distance from traffic and smelters, (Lagerwerff and Specht 1970).

The Cd concentration in corn grains and stover grown on plots amended with sludge were found higher than in the plants on untreated plots (Webber and Beauchamp 1973). Page et al. (1972) have demonstrated significant amounts of cadmium accumulation in leaves of several crop species grown for three weeks in solutions containing Cd as low as 0.1 μg/ml.
From the above studies it is evident that cadmium is a major environmental pollutant. Plants absorb the cadmium and accumulate the element at significant levels.

Considerable variations among the plant species in cadmium uptake and accumulation were reported. Haghiri (1973) reported that soybean (Glycine max L) and winter wheat (Triticum aestivum L) have accumulated only 0-24 µg/g Cd in 5 weeks from a silty clay loam soil containing 0-100 µg/g Cd. Turner (1973) demonstrated that carrot (Daucus carota L) and tomato (Lycopersicum esculentum Mill.) growing in the solution containing 1 µg of Cd have accumulated 2.2 µg/g and 158 µg/g of Cd respectively. Plant growth inhibition was observed at a very low tissue Cd concentration (Allaway 1968). This reduction in growth may partially due to root damage (Lagerwerff and Specht 1970, Turner 1973) and may involve injury to enzyme systems, (Page et al. 1972).

Klein et al. (1981) have determined the upper critical levels of Cd in soil and in tissues of crop plants by studying the yield, biochemical and physiological processes and Cd content of edible plant parts. They have observed reductions in dry matter yield at 10-30 ppm Cd in soil and 16-40 ppm Cd in plant tissues.
Investigation on the zinc and cadmium contents in leaves of 60 species of 37 genera belonging to 24 families growing in the natural forests showed variations in the levels among the plant species. Further, studies on Cd and Mn flux in eel grass *Zostera marina* between leaf and root rhizome tissues revealed that root rhizome is a sink for Cd (Brinkhuis et al. 1980).

The greater accumulation of Cd by bean roots than shoots was observed by Rodecap et al. (1981) and in other plant species by Jastrow and Koepp (1980). Cunnigham et al. (1975) attributed the Cd distribution in soybean to several long distance transport mechanisms including cation exchange phenomena, diffusion and control by ongoing metabolism. The mobility of Cd within plants also may be related to the solubility of cadmium phosphate (Jarvis et al. 1976, Jarvis and Jones, 1973). Weigel and Jager (1980) determined that Cd was associated with higher molecular weight components in bean roots than in the shoots, suggesting that the observed distribution may be due to differential translocation of higher and lower molecular weight organo-cadmium complexes within the plants. And Cd is known to interfere with nutrient elements (Root et al. 1975, Oberlander and Roth 1978).
The distribution and chemical behaviour of Cd\(^{2+}\) in tissues and form in xylem water of soybean plants were investigated by Cataldo et al. (1981) by applying Cd to the culture solutions. They have observed that Cd is strongly retained by the roots, while with only 2% of accumulated Cd being transferred to leaves and as much as 8% was transported to seeds during seed filling. The xylem sap contained 2 anionic Cd complexes in addition to organic forms. The Cd accumulated in soybean seeds was primarily associated with cotyledons.

Similarity between the transport of Ca\(^{2+}\) and Cd\(^{2+}\) has been described by Petit and Geijn (1973). Both cations are transported in the xylem by exchange along the native charge sites. At low levels of Ca nutrition Cd incorporation was relatively high into the oxalate crystals (Van Halen et al., 1980). Cd seems to be found in intercellular spaces, cortex, phloem, epidermal cells, endodermis and low amounts in pith. The deposition of Cd in primary xylem vessels and internal phloem in this case may be related to a pattern of nutrient acculation in tomato plants (Sonnermain, 1972).
The visual toxic symptoms of Cd toxicity include reddish brown discolouration of leaf veins, petioles and stems; leaves were cupped and rolled downwards. It was shown that the tomato leaves develop interveinal chlorosis and necrosis when treated with Cd. Drastic yield reductions were also observed (Volz and Chambliss 1979).

Though a few reports on Cd toxicity in plants appeared (Bazzaz et al. 1974, Cunningham et al. 1975, Koepp et al. 1973, Foy et al. 1978) still molecular basis of Cd toxicity in higher plants remains largely unknown.

Cadmium has been reported to inhibit certain physiological process in plants. It was reported that Cd inhibits the photosynthesis and transpiration in detached leaves of sunflower and corn. It was suggested that this inhibition may be due to the closure of stomata in detached leaves with CdCl₂ solutions (Bazzaz et al. 1974a).

The heavy metals such as zinc, cadmium and mercury have been reported to inhibit the respiratory O₂ uptake and photosynthetic O₂ evolution in Euglena (DeFilippis et al. 1981 b). PSII associated electron transport is more inhibited than PSI activity in isolated chloroplast
by CdCl₂ solution. Cadmium, zinc and mercury inhibited
NADP oxidoreductase activity thereby reducing the levels
of NADPH, the reducing power needed for driving the
Calvin cycle.

In corn and sunflower detached leaves cadmium has
inhibited respiration. Cadmium reported to inhibit the
O₂ uptake and NADH oxidation in isolated mitochondria
from corn leaves (Miller et al. 1973).

Cadmium inhibition of NO₃ reductase activity was
reported in detached leaves treated with CdCl₂ solution
(Venkataramana et al. 1979). Cd may interfere specifically
with plant metabolism by affecting the process of cell
regulation. The effects of Cd on in vivo and in vitro
studies of MDH protein and on in vitro studies of GDH
protein suggest a direct contact of Cd ions leading to
an inhibition of respective enzyme activities. The
influence of Cd on the regulation of the amino acid
metabolism and of the Krebs cycle may be one reason for
the phytotoxicity of element (Weigel and Jager 1980).
The strong affinity of Cd for chain ligands of proteins
(Vallee and Ulmer 1972, Hampp et al. 1976) strongly
suggests that enzyme activities are one of the first
metabolic process which the element might interfere in
higher plants. It has been investigated by Weigel and Jager (1980), that Cd inhibits the activities of enzymes, more the glutamate dehydrogenase and less the malate dehydrogenase from roots and shoots of bean plants. Similar inhibition rates of plant enzymes by heavy metals including Cd were also observed (Haung et al. 1974, Hathys 1975, Hampf et al. 1976). Synthesis of cadmium binding protein in root has been reported and it appeared to be induced by treatment of the tomato plants with Cd (Bartlof et al. 1980).

Heavy metal accumulation and their toxicity in lower groups of plants have also been reported. The heavy metals on growth of marine phytoplankton has been well documented in the literature (Spencer 1957, Chipman et al. 1958, Hayward 1969, Mandelli 1969, Russell and Morris 1970, Coleman et al. 1971, Orrnell 1975 b, Nakano et al. 1981).

Chlorella vulgaris has been reported to be tolerant to some heavy metals including Cd, Cu, Pb, Ba and Mn (Russell 1962). Porphyra umbilicalis a marine red alga has been reported to accumulate unusual concentrations of Cd (McLean and Williamson 1977). A brown sea weed, Fucus vesiculosus L accumulated Cd in physodes and cell walls in outer layers (Lignell et al. 1982).
Studies on long term impacts of increased metal loading (Hg, Cu, Cd, Zn and Pb) on phytoplankton communities revealed that increased metal concentrations have lowered initially the phytoplankton biomass, species number and their photosynthetic activity.

The in situ studies on the long term uptake and release of heavy metals including Cd by sea weed, Ascophyllum nodosum revealed that Zn and Cd were taken up very slowly in the winter and quick in summer. Release of Zn, Cd, Pb and Hg showed seasonal variation. Uptake and accumulation of Zn and Cd has reported to require input of metabolic energy (Eide et al. 1981).

A few microorganisms have been reported to have developed resistance to toxic quantities of heavy metals commonly used for land application (Ashida 1965, Amworth and Am in 1964). Agaricus bisporus was found to accumulate Cd and Hg significantly via the mycelium (Enke et al. 1979). Heavy metal toxicity and tolerance have also been reported in bryophytes and pteridophytes although the work on pteridophytes is scanty.
Besides Cd toxicity in plants, Cd tolerance has also been reported in certain plants. Coughtrey and Martin (1977, 1979) have observed the tolerance potentials in *Holcus lanatus* to high concentration of cadmium.

The present work specifically aims to understand the deleterious effects of cadmium ions on the germination, growth, morphology and some physiological aspects of *P. aureus* Roxb.