INTRODUCTION
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The heavy metals, defined by Passow et al. (1961) are those metals having a density greater than five or having an atomic number greater than iron, include about thirty eight elements. Their common features in relation to biological life is that, in excessive quantities, they are poisonous and can cause death of most living organisms (Antonovics et al., 1971).

Although the term 'heavy metal' is well established in the literature, its definition is based on a rather arbitrarily chosen parameter and consequently includes elements with widely different chemical properties. Some metals are essential (e.g. Cr, Co, Cu, Ni, Sn, Zn) for the life functions of plants and animals and only pose a problem when their concentrations in air, soil or water are significantly elevated above natural levels by human activities. In this way investigations of heavy metals differ from studies of organic compounds (e.g. pesticides) or man-made radio-nuclides, where detection is itself an indication of contamination (Davies, 1980).

Heavy metals are toxic at relatively low concentration, the toxicity is not an exclusive characteristic of elements classed as heavy metals. Heavy metals are a heterogenous group of elements which greatly differ in their chemical properties and biological functions. Thus the term 'heavy
metal' is discredited (Woolhouse, 1983). The term 'trace metal' or 'trace element' is preferred (Phipps, 1981). Tiller (1989) pointed out that 'heavy metal' may be a useful umbrella term for metals classed as environmental pollutants.

Other heavy metals including the most common pollutants (Hg, Cd, Pb) not yet identified as serving a beneficial function, are termed as non-essential and are toxic even at low concentrations. In relation to environmental pollution, heavy metals which are very toxic, relatively abundant in nature and readily available as soluble species pose the greatest threat to biological systems (Wittmann, 1981). Heavy metals are integrated components of the biosphere and thus occur naturally in soil and in plants. Five heavy metals (Fe, Mn, Cu, Zn, Mo) are essential for all higher plants (Marschner, 1983).

Heavy metal toxicity was not generally regarded as an agricultural or horticultural problem. It was only a decade ago that the role of elevated heavy metal toxicity in animals and man suddenly attained overwhelming importance. The well known example was the occurrence of the human sickness Itai-Itai in Japan, caused by cadmium released from industrial areas and passed at least in part from the soil into the food chain via plants (Yamagata and Shigematsu, 1970). Minamata disease in Japan was another example of heavy metal, i.e. mercury toxicity (Kurland et al., 1960).
Soil covering ore-bearing rock or slag heaps contains heavy metal ions (especially Zn\(^{+2}\), Pb\(^{+2}\), Ni\(^{+2}\), Cd\(^{+2}\), Cr\(^{+2}\) and Cu\(^{+2}\)) and Mn\(^{+2}\), Mg\(^{+2}\), Cd\(^{+2}\) and Se\(^{+2}\) in amounts toxic to most plants (Larcher, 1983). Macklin (1992) discussed the nature, history, sources, pathways and targets of heavy metals in the environment.

Copper is an essential microelement for plants (Sommer, 1931; Lipman and McKinney, 1931) though it can also be a toxic element if its concentration is more. Metal smelters or mine tailings are the sources of copper pollution. Excess copper causes disturbances in physiological and biochemical processes. Copper has a strong binding capacity to organic matter. Thus limited fraction of the total amount of copper present in the soil is available to plants. Since, copper is widely used in industries, its concentration is enormously increased in the environment (Freedman and Hutchinson, 1980; Humphreys and Nicholls, 1984).

Copper plays an important role in the metabolism because number of enzymes contain copper as prosthetic group. The role of copper in agricultural crops is discussed by Gupta (1979). Plants growing near copper pollution sources contain high levels of copper in their tissue (Larcher, 1980; Gonzalez and Bergavist, 1986). Excess copper inhibits number of enzymes. The remarkable effect is found with photosynthetic electron transfer (Bohner et al., 1980). Copper is an effective inhibitor of vegetative growth.
and it induces symptoms of senescence. Copper toxicity in plants is discussed by Levitt (1980).

Cadmium is associated with zinc and it occurs in low concentrations in nature. It is of major concern and rather a recent problem as is indicated by the production and uses of this element has increased worldwide (Page et al., 1972). Cadmium is recognised as an important trace contaminant in both aquatic and terrestrial environment. It is released into the environment through its deceptive uses. Chronic effects of cadmium compounds were first recognised by Nordberg (1974) and Friberg et al. (1974). Its phytotoxicity has been reported by number of workers (Page et al., 1972; Friberg et al., 1974; Foroughi et al., 1976; Kloke and Schenke, 1979). Cadmium is known to affect photosynthesis, transpiration, respiration and activities of several enzymes (Bazzaz et al., 1974; Lee et al., 1976).

Cadmium is taken up quite readily by many crop species, which is one of the most toxic heavy metals for animals and man (Page and Bingham, 1973; Vetter et al., 1974; Doyle, 1977; Chaney and Hornick, 1978).

Mercury is non-essential and toxic to the plants. Low levels of natural mercury are distributed throughout the environment in a harmless form. In natural environment, mercury is found in soil, air and water. The natural occurrence as well as man-made sources of mercury are
described (WHO, 1991). Mercury can enter the environment directly or indirectly. Mercury is one of the four metals of environmental concern. The higher anthropogenic activity and natural processes associated with mercury release are the causes of mercury toxicity (Nriagu, 1988). The well-known sources of mercury contamination are chlor-alkali industry (Lipmann, 1979), paper and pulp industry, paints, pharmaceuticals and industries producing electrical equipments. Mercury compounds used as fungicides in agriculture also increase the levels of mercury in the environment. The total global release of mercury in the atmosphere due to human activity has been estimated to be of 2000-3000 tonnes per year (WHO, 1991).

The toxicity of mercury varies with its chemical form. Mercury is equally toxic in both physical forms - liquid and vapour. Mercury in trace amounts is found throughout the ecosystem, in soil, water, air and in living species. It is extremely mobile in the environment. Natural cycles transform and transport mercury in wide varieties of manners through air, water and soil (Sitting, 1976). The difference is small between the background mercury levels and levels that are toxic to organisms (Paasivirta, 1991; Munthe and McElroy, 1992).

Toxic effects of mercury in plants include growth reduction, general distressed vigour, abscission of older leaves (Heck and Brandt, 1971), inhibition of root and leaf
development (Siegel et al., 1973) and leaf necrosis (Waldron and Terry, 1975). Mercury affects living membranes and their functions in several ways.

Heavy metals induce a series of biochemical and physiological alterations in plants which present some common characteristics. Membrane damage, alteration of enzymic activities and inhibition of root growth are considered to be the characteristic features of heavy metal stress (Foy et al., 1978; Lepp, 1981).

Some plants have the ability to adapt or tolerate the heavy metal toxicity. The ability of plants to deal with toxic amounts of heavy metals is at the root surface. The biochemical changes occurring at the root surface have been described by Woolhouse (1970) who examined the activity of acid phosphatase present in the roots of Agrostis tenuis. The enzymes at the root surface are adapted to high metal concentrations and can function inspite of the high toxic metal content in their environment. In short, there are series of heavy metal binding peptides produced in plants which have the ability to chelate these cations.

Metal toxicity is the result of complex interaction of the major toxic ions with other essential or non-essential ions and with other environmental factors. Excess of various metals may produce some common effects on plants. Still there are cases showing that individual metal gives specific differential effects on different plant genotypes. Such
effects must be recognised in approaching any problem of metal toxicity. Phytotoxic mechanism of metals involved different biochemical pathways in different plant species and varieties.

Biochemical adaptation in plants to heavy metals involves several mechanisms, binding at cell wall, complexing with phytochelation, complexing with organic acids, transportation and compartmentation. Metal accumulation and hence tolerance is metal specific and each metal cation represents a different problem to the plant. Plants do, however show co-tolerance, e.g. to Zn and Cu and multiple metal tolerance has been recorded (Peterson, 1983), so that there may be some mechanisms which are common to more than one metal.

Maize and wheat are important cereal crops, raised through seed germination. Seed germination and seedling growth are essential and important in such crops. The physiology and biochemistry of seed germination is discussed (Khan, 1977; Bewley and Black, 1982; 1985; Murray, 1984). Information is available on early events in germination, mobilization of reserves from endosperm, environmental control of seed germination etc. Seed germination is affected by number of environmental factors like light, temperature, water etc.

The presence of heavy metals in the soil is also an
important factor influencing seed germination and seedling growth. The effects of any factor on physiological and biochemical processes depend upon the intensity and duration of factor as well as the age of the seedlings. Any unfavourable factor for growth and development in plants is considered as stress. High heavy metal availability causes an ion stress in plants, which is very much distinct from salt stress (Levitt, 1980).

In arid region there is a shortage of water and sewage is often used for irrigation, since it is also a valuable source of macro and micronutrients required for plant growth. In India such water is used whenever drought occurs. Anon (1982) reported that sewage available from big cities in India could annually contribute 33,000 tonnes of N, 7000 tonnes of P and 20,000 tonnes of K. Sometimes this water remains untreated and untreated water contains heavy metals. Anthropogenic activities also add heavy metals to soil, water etc. Thus, waste water discharge from sewage has become a source of trace and heavy metals (Davis and Jacknow, 1975).

Maize (Zea mays L. var. Ganga Safed-2) and wheat (Triticum aestivum L. var. Sonalika) are prominent varieties and widely cultivated by farmers. Different species have different abilities to cope up with adverse conditions, i.e. stress. Effects of water stress, salt stress on growth and metabolism of these crops are studied well, little is known
about the effects of heavy metals like Cu, Cd and Hg having same range of concentration on these crops at seedling stage. These two crops were selected for studying the effects of heavy metals on their growth.

Growth is the sum of all metabolic activities and as heavy metals greatly influence the growth and metabolism, it is very essential to study the various metabolisms in heavy metal grown plants. Such study will help in evaluating the toxicity and tolerance of particular species to particular heavy metal.

Looking to the above mentioned points, following experiments were performed.

EXPERIMENT I : EFFECTS OF HEAVY METALS ON GROWTH AND METABOLISM OF MAIZE AND WHEAT SEEDLINGS (PETRIPLATE EXPERIMENT):

Graded seeds of maize (Zea mays L. var. Ganga Safed-2) and wheat (Triticum aestivum L. var. Sonalika) were germinated in petriplates lined with sterilized filter paper under laboratory conditions (28±2°C). The experiment was carried out upto 120h in case of maize, upto 96h in case of wheat. The media were DW, 50, 100, 150, 200, 250 and 300 μg/ml of copper chloride, cadmium chloride and mercuric chloride each. The percent germination was recorded. The seedling growth in terms of elongation, fresh weight, dry weight and percent moisture were recorded from DW and heavy
metal grown seedlings at the intervals of 24h and that upto 120/96h. The embryo and endosperm in triplicate of these seedlings were analysed for the following metabolic activities.

(1) Carbohydrate metabolism:

(2) Protein Metabolism:
   (vii) Protease, (viii) Protein, (ix) Total amino acids, (x) Proline.

(3) RNA Metabolism:
   (xi) RNAse activity, (xii) RNA content.

(4) Phosphatases:
   (xiii) Acid phosphatase.

(5) Oxidising Enzymes:
   (xiv) Peroxidase, (xv) Polyphenol oxidase.

(6) Phenolic substances:
   (xvi) Total phenol content.
EXPERIMENT II : EFFECTS OF HEAVY METALS ON GROWTH AND METABOLISM OF MAIZE AND WHEAT SEEDLINGS (POT CULTURE EXPERIMENT):

Graded seeds of maize var. Ganga Safed-2 and wheat var. Sonalika were sown in earthen pots filled with sterilized sand. Seedlings raised without heavy metals were considered as control. Heavy metals were mixed in the sand before sowing. The concentrations of CuCl₂, CdCl₂ and HgCl₂ were 50, 100, 150, 200, 250 and 300 mg/kg sand. The experiment was carried out up to 10 days under laboratory conditions (28±2°C). The percent germination was recorded. The elongation of root and stem, leaf number, fresh weight, dry weight, percent moisture of root, stem, leaf and endosperm were recorded at the end of 6th, 8th and 10th day. The uppermost unfolded leaf of 6, 8 and 10 days old control and treated seedlings were analysed for enzymic activities and metabolic contents. The biochemical parameters were same as studied in experiment I. The leaf of 10 day old seedlings was also analysed for chlorophyll 'a', chlorophyll 'b', total chlorophyll and carotenoids.

The data on all biochemical parameters (Expt. I & II) were subjected to analysis of variance for finding out the significance of the treatments.