INTRODUCTION

Heavy metals are integrated components of the biosphere and thus occur naturally in soil and plants. 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. By common usage, heavy metals appear to include all metals of the periodic table with atomic numbers greater than 20, generally excluding the alkali metals and alkali earths. 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).

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).

The end of the cold war resulted in the closure of many facilities that produced nuclear and chemical weapons worldwide, but it also left behind a legacy of environmental contamination. The toxic metals produced by metal fabrication industries are found in waste. The toxic metals are Cd, Cr, Cu,
Ni, Pb and Zn (Francis and Dodge, 1998). The growing threat of environmental pollutants including heavy metals appears to be one of the most serious problems confronting the entire mankind (Alloway, 1990).

Heavy metal pollution of soil and vegetation related to atmospheric inputs, such as automobile exhausts and industrial emissions is wellknown. The metal industry is responsible for the dispersion of anthropogenic heavy metals in the environment from mining operations and smelter-refinery processes, with the amount of heavy metals released dependant on the ores being processed: for example, the lead industry can release substantial amounts of Pb, Zn, Cd and Cu (Wixson et al., 1973; Davies and Roberts, 1978; Adriano, 1986).

The heavy metals, when present at an elevated level in the environment, may be taken up by the plants from the soil via the root system and/or by foliar absorption (Lagerwerff and Specht, 1970). Higher plants often take up these metals which eventually exert toxic effect on them (Foy et al., 1978; Woolhouse, 1983) and other plants (Kacabova and Natr, 1986; Mesmar and Jaber, 1991; Hsu and Chang, 1992).

Once heavy metals enter the food chain they tend to accumulate, a process called bio-magnification and can reach toxic levels by the time they are transferred to humans. Fish, for example, filter the water they live in and can therefore accumulate heavy metals in their tissue. The concentration of such accumulated heavy metals (e.g. Hg) can pose a significant health risk to humans who eat contaminated fish. Heavy metals can enter the environment from a variety of sources. One of the most controversial of these sources is industrial waste disposal. Direct discharge of some types of industrial effluent into rivers and lakes has led a series of well documented ecological disasters. Solid waste disposal also has the potential to cause heavy metal pollution of the environment.
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). Wu et al., (1981), Jia (1992) and Yanai et al., (1998) reported the Cd-induced human disease whose symptoms were similar to those of Itai-Itai disease in Japan. Minamata disease in Japan was another example of heavy metal, i.e. mercury toxicity (Kurland et al., 1960).

India provides a typical example of a developing country with a fast rate of industrial growth aimed at high economic and allied benefits. The existing economic superstructure, lack of sufficient data and absence of appropriate legislative measures have so long permitted uncontrolled release of industrial waste. Industrial effluents contain both organic and inorganic wastes which could be toxic to plants, animals and man at high concentrations (Tripathi and Tripathi, 1999).

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 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 in spite
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 phytochelatin, 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 plants. 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.

In many cases of soil pollution, soils are contaminated with more than one heavy metal. As a result of long-term application of large amounts of cattle manure, mineral fertilizers, composts etc. copper, cadmium, zinc, nickel and lead reported in the soil (Keltjens and van Beusichem, 1998). Soil covering ore-bearing rock or slag heaps contains heavy metal ions (especially \( \text{Zn}^{2+}, \text{Pb}^{2+}, \text{Ni}^{2+}, \text{Cd}^{2+}, \text{Cr}^{2+} \) and \( \text{Cu}^{2+} \)) and \( \text{Mn}^{2+}, \text{Mg}^{2+}, \text{Cd}^{2+} \) and \( \text{Se}^{2+} \) in amounts toxic to most plants (Larcher, 1983). Macklin (1992) discussed the nature, history, sources, pathways and targets of heavy metals in the environment.
Cadmium is associated with zinc and it occurs in low concentrations in nature. It is of the 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. The behaviour of Cd in soils is of a particular interest of researchers from both agricultural and environmental viewpoint since Cd enters the soil environment from both natural and anthropogenic sources. The latter is more serious, given that additions are to the soil surface and Cd is therefore accessible for animal and plant uptake. Thus, a major impetus to Cd research has been its potential risk to human health from the ingestion of Cd-contaminated materials (Friberg et al., 1974).

Nowadays, cadmium is being released into the environment in considerable amounts owing to heavy industrialisation. High cadmium has been found to accumulate in soil polluted by traffic exhaust, whereas gasolenes and rubber tyres are additional sources of cadmium (Lagerwerff and Specht, 1970). Cadmium has been reported to be phytotoxic in many physiological and biochemical processes (Page et al., 1981). Cadmium is accumulated in the soils yearly with an average rate of 4% on airable land depending on the use of phosphatic fertilizers, sewage sludge, manure and lime and precipitation of air pollutants (Andersson, 1977).

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; Dolye, 1977; Chaney and Hornick, 1978). 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; van Assche and Clijsters, 1990). Cadmium at low concentration in the environment may cause leaf chlorosis and necrosis and inhibits tissue development. The presence of cadmium disturbed the uptake of mineral nutrients and may cause severe nutrient deficiencies, nutrient balance was disturbed and productivity was affected (Burzynski, 1988., Trivedi and Erdei, 1992; Costa and Morel, 1994; Dudka et al., 1996). Cadmium does not play essential role in the plant metabolism, although it occurs naturally in all plants (Kabata-Pendias and Pendias, 1984).

Mercury is one of the top four metals of environmental concern (Nriagu, 1988) due to increased anthropogenic activity and natural processes associated with its release. Hg has no known physiological significance and therefore, is not metabolized by most organisms. Even low concentrations introduced into biological systems may result in serious toxicity for sensitive species along the food chain. Consequences relating to Hg accumulation and transfer through aquatic food chains as methyl mercury have been well documented, as in the case of Minamata disease in Japan (Kurland et al., 1960). Mercury is non-essential and toxic to the plants. Low levels of natural mercury are distributed through 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. 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 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.

India is well known historically as a land of spices. Spices like Black Pepper, Cardamom, Long Pepper, Cinnamon, Turmeric, Ginger etc. were common export items for hundreds of years. Some of the other spice crops like Cumin, Fennel, Fenugreek, Coriander, Clove, Nutmeg etc. were introduced at various points of time into India. India also is the major exporter of spices in the world (Rao, 1991). Cumin (Cuminum cyminum L. Family- Apiaceae (Umbelliferae)) is an annual herb, having much-branched angular stem. The dried fruit, commonly called cumin seed has a strong distinctive pleasant odour and some-what bitter taste due to the presence of volatile oil. The cumin seeds is an important ingredient in curry powder and is mainly for flavouring soups, sausages, cheese, meat dishes, bread and cakes. In indigenous medicine cumin seeds have long been considered as stimulant and carminative. They are stomachic, astringent and useful in dyspepsia.
The seeds are also used in veterinary medicine. The residue left after the extraction of volatile oil can be used as cattle feed. Cumin is a source of valuable foreign exchange for the country (Kochhar, 1981, 1998). Cumin seeds are very rich in an essential oil, it is an anthelmentic against hook-worm infections and also antispetic. The seeds are a rich source of thymol (Sundararaj and Thulasidas, 1976). The dried seeds after stem distillation yield 2.5% of essential oil (Varo and Heinz, 1970). Guenther (1972) and DeMayo (1959) reported that cumin aldehyde is the most prominent carbonyl in the essential oil. Agrawal and Patwardhan (1990) suggested that the formation of cumin aldehyde is the major flavour ingredient in the cultures of Cuminum cyminum.

In India, Gujarat is the leading state so far as the cultivation and production of spices are concerned, and it is most extensively grown in North Gujarat. The effects of heavy metals like cadmium and mercury are generally studied in cereals, legume, oil-crops such study it still rare in spice crops. Looking to the importance of cumin (local name jera), var. Guj-1, it was selected for the study.

The following were the objectives to study the heavy metal toxicity in cumin.

1. To study the growth response of cumin grown on cadmium and mercury contaminated soil.

2. To estimate the photosynthetic pigments, selected enzymic activities and metabolites in cumin raised on cadmium and mercury contaminated soil.

3. To determine the level of cadmium and mercury in cumin raised on cadmium and mercury contaminated soil.
(4) To study the effects of foliar application of cadmium and mercury on growth of cumin.

(5) To study the effects of foliar application of cadmium and mercury on photosynthetic pigments, selected enzyme activities and metabolites in cumin.

(6) To determine the level of cadmium and mercury in cumin receiving foliar application of cadmium and mercury.