Introduction

INTRODUCTION

Urbanisation and industrialisation has resulted in the impoverishment of the environment. Many industrial processes such as coal and oil combustion, and roasting of some mineral ores produce sulphur dioxide and nitrogen oxides which are released into the environment. In many developed countries, emissions and ambient air pollutant concentrations are decreasing due to national and international policies; however, sulphur dioxide concentrations in many cities in developing countries are still increasing. Ambient air concentrations of nitrogen oxides are increasing in cities in both developing and developed countries around the world (GEMS 1988). The atmosphere of cities and areas near heavy industries usually contain mixture of sulphur and nitrogen dioxides (Murray *et al* 1994[c]).

Industries sustain a large mass of people which causes their dwelling in congested and `environmentally unmanaged' projections. In order to gain more, industries often go on widening by ignoring environmental laws Many times pollution control boards fail to regulate. This results in the air, water, and soil pollution around industrial areas which may prove hazardous to plants, animals and human beings. Untreated by-products and other wastes, emitted or discharged from the industries can cause disturbance at landscape level. There are examples of disturbances at various scales (Cairns Jr. & Niederlehner 1996). Those are

1. Local : Heavy metal pollution, Oil spills.
2. Landscape · Air pollution, Pesticides, Fertilizers/Nutrients
3. Regional : Air pollution, Salinization
4. Continental : Air pollution-"Acid rain",Chemically mediated changes inUV-B
5. Global : Increase in atmospheric CO_2.

"Air Pollution" means "the presence of any solid, liquid or gaseous substance in the atmosphere as may be or tend to be injurious to human beings or other living creatures or vegetation or property or environment" [*The Air* (prevention and control) *Act*, 1981; Cl (b)]. This will not only cover the industrial air pollution, rather it will include all kinds of operations like burning of rice and wheat straw in the fields etc. causing air pollution (Garg & Tiwana 1995)

AIR POLLUTION AND PLANTS

Due to air pollutants, damage to the plants, is a trite If a vista of their impacts are to be contemplated, it will appear that it has got frivolous importance. More recently, air pollution studies implemented with different methods, fields of study and perceptions have drawn serious attention. Air pollution studies on vegetation is a common (and/or easy to) practice. There is ample literature on plants being used as indicators or studied for air pollution monitoring. It has been studied under field conditions (in agricultural lands, forest stands and ruderals), semifield conditions (in open-top chambers with artificial nutrients and gaseous mixtures) or under fully controlled laboratory regimes. Investigation techniques used in air pollution assessments on crops have their limitations, with field experiments never offering proof of causal relationship, while controlled laboratory conditions are highly artificial (Houlden *et al.* 1990) Earlier, prognoses were made pragmatically for one pollutant impact on one or more plant species. Later on, synergistic effects (mostly with ozone and oxides of nitrogen and sulphur) are experimented bounteously. Plant's morphological, phenological, physiological and anatomical studies have been conducted under laboratory conditions (Pearson & Mansfield 1993, Murray *et al.* 1994[a], Smeulders *et al.* 1994). Pure ecological studies under field conditions for atmospheric deposition have also been carried out (Steubing *et al.* 1989, Shaw *et al.* 1993, Edwards *et al.* 1994, Fredericksen *et al* 1995) Many others have studied atmospheric depositions for more broader base (Lindberg & Owens 1993). Erisman (1992) has developed an atmospheric deposition model for the Netherlands, by using satellite data and receptor monitoring on open fields and forests Draaijers (1993) has estimated canopy interactions for three types of forest (i.e. Oak, Pine and Spruce) stands by assessing atmospheric depositions onto the forests.

Air pollutants **enter** through stomata or penetrate through cuticular membrane either directly by diffusion or by damaging it They damage softer tissues and finally decolouration of foliar surfaces appear as chlorotic and necrotic patches. Under extreme levels of exposure, death or suppression of apical bud, and heavy leaf fall sets in, altering the phenological cycle and reducing the biomass.

Impact of air pollution on plants can be broadly categorised into

Changes in Physiology

Air pollutants disrupt the normal physiological processes and hamper photosynthesis. Darrall (1989) observed irregular stomatal function during SO_2 fumigation. Edwards *et al.* (1994) have reported reduced gas exchange rates and photosynthesis in red oak trees due to ozone Similarly, modified carbon metabolism enzymes have been predicted by Gerant *et al* (1996) on expense of growth was due to change in gas exchange (i.e. net CO_2 assimilation rate and stomatal conductance) capacity. Inhibition of the translocation of photosynthates by ozone has been described earlier (Adams *et al.* 1990). Retention of translocates in the needles of conifers has also been reported by others (i.e McLaughlin *et al* 1982, Gorrisen *et al.* 1991, Friend & Tomlinson 1992, Kelly *et al.* 1993). Steubing *et al.* (1989) have found altered carbohydrate metabolism due to fumigation leading to starch accumulation in leaves.

Visible Symptoms

Physiological changes may result in the discolouration due to the collapse of chlorophyll which result in the development/formation of chlorotic yellow patches on the foliar surfaces. Consequently it develops into necrotic brown lessions. Microscopical observations reveal some of the morphological changes such as clogged stomata, eroded cuticular surfaces and disrupted leaf hairs In Europe and

NE USA, much of the foliar damage/discolouration that has been widely observed on Norway and red spruce (*Picea abies* L. Karst, P. *rubens* Sarg.) has been confidently attributed to direct or indirect effects of atmospheric pollutants, particularly at high elevations (Schultze *et al.* 1989, Eagar & Adams 1992). For the Norway spruce needles, first two weeks after their flushing are found to be critical with respect to development and formation of epicuticular wax due to air contaminants (Tenberge 1992). Leith *et al.* (1995[a]) reported that treated clones of sitka spruce with acid mist, have shown 2-18 % of damaged needles Similarly for the same plant, Percy and Baker (1991) have seen increased wettability with the commencement of acid mist treatment. Cuticles exposed to acid mist exhibit differences in structure and composition (Huttunen 1994, Percy *et al.* 1994). Chen *et al.* (1991) have compared foliar injury with the antioxidant levels in red and Norway spruce, when exposed to acidic mists.

Reduction in growth and plant biomass production

Under the influence of air pollution loads (at higher pollutant concentrations) plants often show either reduced or damaged foliar surfaces which can reduce the over all plant growth. Woodbury *et al.* (1994) have found reduced leaf area in *Poplus* plants when exposed to ozone. Though leaf (produced) number increased, there was decreased basal diameter, height and weight of the stem with reduced internodal length This was observed with increased shoot/root ratio Higher oxides of nitrogen treatments have shown reduced growth as compared to it's lower concentrations and unpolluted treatments (Pearson *et al* 1994). Ayer and Bedi (1991) have seen decreased growth performances in wheat cultivar at all the ages of plants towards windward direction of the industries Similarly under field conditions, Kord *et al.* (1993) have observed decreased growth parameters under the influence of H_2S fumigation in radish plants. When tomato plants were exposed to different combinations of O_3 and SO_2, both gases singly or synergistically have significantly depressed dry matter (Khan & Khan 1994) *Mimusops elangi*, an evergreen species was subjected to see the effect of NO_2. Decrease in root/shoot ratio, fresh and dry weights were found by Tiwari and Bansal (1993). Rantanen *et al.* (1994) have studied the combined exposure of SO_2 and NO_2. They have found an uptake of sulphur and nitrogen in trees with reduced growth. Growth parameter studies thus can be an important tool in determining a plant's/tree's growth performance and vitality to withstand against air pollution loads.

Altered Phenology

Climatic fluctuations, exposures to atmospheric emissions originating from the industrial estates and summer concentrations of ozone were considered to be bad for the conditions of holm oak tree crowns of mediterranean forests (Bussotti *et al.* 1995). Ferretti *et al.* (1995[a]) have seen phenological abnormality, whereby all leaves of trees were shed (crown transparency) and replaced during sprouting period and that was accompanied by an exceedingly abundant male flowering. Ozone exposures accelerated autumn leaf fall in old leaves (Klumpp *et al.* 1988, MacLean 1990, Mortensen & Skre 1990, Wiltshire *et al.* 1993). Trees having high sensitivity have shown increased rate of leaf shedding with a rise in ethylene concentration and temperature (Sawada *et al.*1989). Ozone can induce xeromorphic (type) changes in broad-leaves (Gunthard-Goerg *et al.* 1993). Recently with the help of remote sensing, phenological study in context to environmental pollution has been started. Silvennoinen *et al.* (1995) used pine reflectance spectra to classify pine growing in polluted and less polluted environments They found different spectral resolutions due to obvious phenological shift which is studied for spatial and temporal environmental classifications.

Based on all these attributes, plants can be used as **biomonitor** tools. Stationary habit makes them to face and withstand against any types of environmental stresses including air pollution. In Europe and N. America, active monitoring with bioindicators (especially vegetation) are widely used to monitor air quality (Manning & Feder 1980, Arndt *et al.* 1987) In Israel, lichens and higher plants were exposed near industrial areas to detect the accumulation of heavy metals in plant material and to assess the impact of gaseous air pollutants respectively (Naveh *et al.* 1979, Garty 1987). Several indicator species have been used to map the extent of air pollution by phytochemical oxidants in Mexico (deBaur & Krupa 1990, Gonzelez & Rivas 1992). In Brazil, studies have been performed on suitability of orchids, *Tillandsia* and *Ipomoea* species as bioindicators (Strehl & Lobo 1989, Arndt *et al.* 1991). Klumpp *et al.* (1994) have reported high degree of injury coincided with strongly elevated leaf fluoride content in the leaves of *Gladiolus* and *Lolium*

In India too, phytomonitoring has been studied since three decades Chaphekar (1972) studied visible injuries on plants through vegetational surveys in Mumbai. Some plants were exposed and based on visible symptoms they were classified as sensitive or tolerant species (Chaphekar & Karbhari 1974). Rao (1981) used alfalfa and *Gladiolus* for SO_2, and maize for HF as sensitive species to specific pollutants. He also emphasised spatial and temporal gradients by exposing these sensitive species at various distances from the source and for different durations. Ahmad *et al.* (1991) have studied a large number of trees, shrubs and herbs growing naturally in fields around thermal power station They listed out tolerant and sensitive plants (Table 1) for landscaping urban and industrial areas for air pollution abatement.

Vegetation as sinks for air pollutants

Vegetation can also act as natural sink for most of the atmospheric pollutants while acting as a chief living component of biogeochemical cycling in terrestrial ecosystems. There is substantial literature on plants as "pollution sinks". Sulphate in pine needles from polluted sites were 2-3 fold higher than in the non-polluted site (Polle *et al.* 1994) Similarly, Sturaro *et al.* (1993) have found detoxification of SO_2 as sulphate, which remained in barley leaves Higher plants emit hydrogen sulphide (H_2S) into the atmosphere in the presence of SO_2 or when supplied with an excess of sulphate or L-cysteine (Rennenberg 1984) SO_2 may be detoxified by oxidation which yields sulphate or by reduction, which finally yields organic compounds Gymnosperms growing side by side in an atmosphere polluted by SO_2 were found to accumulate sulphate to different extents in their needles (Kindermann *et al.* 1995). Nitrogen metabolism and metal accumulation in leaves of trees and bushes planted in the vicinity of factories emitting NO_x, NH_3 and SO_2, have been tested (Sergeichik & Sergeichik 1993) Tolerant species have assimilated the emitted nitrogen Accelerated sorption of nitrogen from polluted soils by plants and detoxification of heavy metal ions by nitrogen compounds is well documented by Evdokimova (1993).

Dry and wet deposition of air pollutants on forest trees is widely studied (Draaijers *et al.* 1988, Lindberg & Lovett 1992). Canopy buffering was discussed by Pedersen *et al.* (1995). They have seen that the buffering pH was affected by nitrogen. Also the fluxes measured for Cl^-, SO_4^{-2}, Na^+ and Mg^{+2} were highest in dormant season and it was less due to elevated levels of organic compounds (i e., leaching took place) in growing season. Air pollutants deposition and their absorption by forest trees showed obvious seasonal discriminations. Okano *et al* (1989) have studied absorption of nitrogen dioxide for various broad leaved species. They found that NO_2 sorption depends on species. For example *Poplus* has the highest rate of NO_2 absorption but is very vulnerable when tested for a mixture of NO_2 and O_3. They also discussed about the purification of the atmosphere by planting NO_2 absorptive species and pointed out the synergistic effect of pollutants. In case of holm oak, there was significant increase in crown density as the distance from the industrial zone increases and leaf concentration of S decreases (Ferretti *et al.* 1995[b]).

Background of the Study

In the literature, the importance of air pollution in vegetational deterioration is well documented. Plant's differential responses and it's air pollutants scavenging is nicely reviewed. Plants as biomonitoring tools, their growth reductions and alterations are also focused. But it is felt that, tropical trees growing around industries in open fields are less studied. Change in growth pattern (phenology) of trees growing in industrial environments too, are less documented/studied

Studies were conducted on trees growing in the Baroda industrial area (Krishnayya & Bedi 1986). It is felt that not all trees present in the study area have been worked out. Earlier, Vijayan and Bedi (1988[a,b,c]) have studied responses of herbs towards industrial air pollution, leaf epidermial studies and fumigation experiments on *Syzygium cumini*. Krishnayya and Bedi (1988) have studied flowering and fruiting in *Moringa pterygosperma* Sample number for all these studies was less and it was felt necessary to study growth parameters 'in detail' to generalise the assumptions for the growth performances of good number of trees. Though, tree phenology plays a major role, no earlier worker had tried to correlate leaf phenology with different biochemical or growth parameters; nor canopy architectural changes (due to air pollution) have been focused. No data exists for a wide range of tree species and localities; similarly, dust scavenging is not quantitatively measured for different species. How a plant with dead apical bud acts on getting favourable conditions or what happens to its phenology and growth ? To address these lacunae the present study has been conducted It is aimed at emphasising the importance of an appropriate growth parameter study together with concurrent phenological changes under field conditions. To generalise the assumptions for synergistic effects of air pollutants in field conditions - more number of localities were selected The localities were with different air pollutant concentrations and with different assortments of trees Tree species selected for the study were considerably more in number and so are the samples (Table 2). Thus, this study is aimed at augmenting the existing knowledge for tree growth and leaf phenology under the influence of industrial air pollution.

Aims of the study are

(1) To study growth patterns of trees under the influence of industrial air pollution, Their comparison between localities and between different tree species.

(2) Recommendation of suitable species for green belts around industries, based on the growth performances and pollution accumulation capacity.