Chapter - I
INTRODUCTION

INTRODUCTION

1. THE ENVIRONMENT AND POLLUTION

1.1.0. The Present Environment

Today's technology constantly places its stress on the environment. It breaks the vital links in the web of biological and physical processes which sustain the ecological system in which man lives. It also destroys man's biological capital - air, water and other components of the ecosystem which must support him and his future generations. Such problems not only cause misery to human beings, as in the case of Bhopal-Gas-Tragedy and Chernboyl-Nuclear Disaster, but also disturb the natural ecosystem at chronic levels causing reduction in the yield of crops, forests and other primary and secondary producers. It is widely known that plants are the saviours of environment and they help to maintain the balance and good health of natural ecosystem. To keep up the levels of organic production and to maintain and enhance the quantity or quality of produce, it is essential to understand the response of plant to the changing environment.

1.1.1. Air Pollution : Is it a new threat ?

A Historical Perspective

Pollution of air requires a special attention due to its importance to biological and other life supporting systems of the biosphere. Air pollution is not a new phenomena. Indeed, it is older than civilization itself. The first episode of air pollution probably occurred when early human-beings tried to make a fire in a poorly ventilated cave. Reference to the polluted air appears as early as, Genesis (19:28): "Abraham beheld the smoke of the country goes up as the smoke of a furnace". About 400 BC, Hippocrates noted the pollution of city air; in 1170, Maimonides, referring to Rome, wrote, "The relation between city air and country air may be compared to the relation between grossly contaminated, filthy air, and its clear, lucid counterpart" (Moran **et al.**, 1986).

It was in the year 1300, king Edward made a royal proclamation prohibiting the burning of coal in London during a session of parliament (Halliday, 1961; Meethan, 1964; Perkins, 1974). In the year 1306 one artificer was executed for the offence (Meethan, 1964; Bibbero and Young, 1974). During the period Charles II in 1661, John Evelyn, an English philanthropist strongly castigated in pamphlets about the decline in the air quality of London (Halliday, 1961; Perkins, 1974; Bibbero and Young, 1974). His protest and suggestion went to oblivion and the problem was set aside until 1819, when the first select committee was appointed to study the problem (Perkins , 1974). The commission failed to solve the problem and the meance continued until it culminated into a few events. The worst event of 1952 inwhich nearly 4,000 people died within a week and 8,000 over the next three months due to smog episode, resulted in the appointment of the Beaver Commission which gave green signal to the Great Britain's Clean Air Act of 1956 (Bibbero and Young, 1974).

Complaints against air pollution were registered elsewhere in Europe and in the United States. Records showed that smoke control laws were adopted by Chicago and Cincinnatic as early as 1881, and by 1912, 23 of the 28 American cities with populations over 2,00,000 had smoke abatement ordinances (Middleton, (1976). Besides these episodes, destruction of local vegetation also caused awareness among the industrialised countries. Number of commissions were appointed to enquire into damage caused by air pollution. In the year 1903, International Joint Boundary Commission investigated an alleged damage to vegetation (at Trial) in British Columbia (Thomas, 1951). Today, in almost all the developed and developing countries special legislations have been imposed to control pollution.

1.1.2. Environmental Awareness in India

It is gratifying to find that India too has evolved smoke nuisance act since 1906, but the act does not seem to have any practical value (Dave, 1976). Nevertheless, the committee on Human Environment was set up in 1970 by Government under the chairmanship of Pitambar Pant (1919-1973), Member, Planning Commission, to prepare a countrywide report for the UN Conference on Human Environment held in Stockholm. This committee went into different aspects and indicated the need for establishing a formal system to ensure greater co-ordination and integration in environmental policies and programmes. Pursuant to the decisions taken at the Stockholm conference in 1972, the Government of India enacted the Prevention and Control of Pollution Acts - Water Act (1974), Water Cess Act (1974) and Air Act 1981 and the Minimal National Standards (MINAS). In January, 1985 a new Ministry of Environment and Forests was created for the effective enforcement of these Acts. This was followed by the Environment (Protection) Act, 1986 whereunder the Government assumed wide ranging powers to implement speedily the pollution control measures to keep the environment clean. The exercise of the powers under the new Act cannot be challanged in a court of law (Anonymous, 1986 a; Pachaiyapan and Nand, 1987).

1.1.3. The Concept of Air Pollution

In the beginning of 17th century the concept of Air Pollution was centred on smoke and soot only and the existence of specific gaseous pollutants was not known. Nevertheless in the later part of 17th century it was known that sulphur in the coal was responsible for the annoyance (Halliday, 1961). Improved instrumentation and monitoring networks had made the concept to change accordingly. The present concept defines the air pollution as "the presence of any contaminants such as dust, fumes, gas, mist, odour, smoke or vapour in the atmosphere to cause injury to human, plant or animal life or to interfere unreasonably with the comfortable enjoyment of life and property (Lapides, 1974). In other words, "Pollution" in general is thought of as any departure from what is perceived to be the natural order of things (Barbour, 1982).

1.1.4. Effects of Air Pollution - General

1.1.4.1 On Physical Environment

The presence of air pollutants can damage physical materials by the process of abrasion, deposition, direct and indirect chemical effects and electrochemical corrosion. It also affects buildings, metals, fabrics, paints, papers, and rubber. The finest monuments of antiquity, famous historic buildings and art materials are deteriorating due to the corrosive effects of air pollution (Yocom and Upham, 1977)

The air pollutants can also affect ambient temperatures through the absorption of radiant energy. The possible effects of increasing global carbon dioxide concentrations have been publicized frequently in this regard. Added to this nitrogen dioxide and aerosols may also be factors in some local urban areas (Robinson, 1977). Further, for instance, the power industry is one of the largest and fastest-growing polluter in the world. Some scientists predict that by the year 2,000, even if all the problems of controlling sulfur dioxide, nitrogen oxides, and radioactive wastes were solved, waste heat from power plants would be enough to cause a 20°F (11°C) increase in the temperature of the total volume of surface water that runs off the land in a year (Bogan, 1976).

1.1.4.2 On Biological Life

(i) On Human Health

Air pollutants are the primary agents of respiratory ailments (Southwick, 1976). They can affect the human body through contact with skin, eyes and enter the body through respiratory system causing different types of respiratory diseases like bronchitis, asthma and lung cancer (Masters, 1974). General effects ranges from chronic diseases to acute sickness or death by shortening the life. Specific pollutants like ozone and PAN causes eye irritation, headache and nausea. Pollutants like carbon monoxide can bind with the hemoglobin molecules and increase the level of carboxyhemoglobin in the blood which ultimately impairs the oxygen uptake. Gaseous fluoride affects the human beings through the food chain causing fluorosis. Though the list is inconclusive in this aspect it can be restricted herewith as our main emphasis laid on the effects of air pollution on plants.

(ii) On Plant Life

Damage to the vegetation due to air pollution has been known since the later part of 19th century (Thomas, 1951). The studies of Gorham and Gordon (1960) near a metal smelter at Falconbridge, and Gordon and Gorham (1963) near an iron-sintering plant at Wawa of Ontario by gradient analysis showed a drastic decline in the flora of the region due to air pollution. Toxic gases at high concentration may cause complex and irrecoverable damage to the structure and functioning of the ecosystem. Before the commissioning of the great Tennesse mining and smelting operations in the Eastern United States the entire area was full of dense mixed hard wood forest, and after the operations started in the year 1913, damage to vegetation was noted up to 15 miles, the central zone of 7,000 acres was completely barren and a belt of 17,000 acres had only **Andropogon** and a few other grasses (Miller and McBride, 1975). Recent studies of Betul forest area near Satpura Thermal Power Plant, M.P., India can also be enlisted under vegetational damage due to air pollution (Dubey **et al.**, 1982).

1.2 Effects of Air Pollution on Growth and Yield

1.2.1 General Symptoms on Plants

Injury effects can be either visible or subtle (Heck and Brandt, 1977). Visible symptom consists of chlorotic or necrotic foliar pattern. Visible injury is further classified as acute or chronic : acute is associated with short term exposure to high concentration of pollutants and chronic effect is due to long term exposure to low concentrations. Subtle effects do not normally result in visible injury but are measurable at physiological level.

1.2.2 Systemics of the Pollutants

Pollutants in the atmosphere are generally classified as primary and secondary pollutants. Air pollutants emitted directly from industrial technology are primary pollutants, while those formed from primary pollutants through atmospheric transformations are secondary pollutants. List of some of the more important phytotoxic air pollutants in the order of importance to plant systems under primary are SO_2, NO_2, HF, ethylene, NO, Cl_2, HCl, NH_3, H_2S and CO_2 and under secondary are O_3, sometimes NO_2, PAN (Peroxyacetyl nitrate) oxidant, SO_4^{2-} and NO_3^- (Heck, 1982). The secondary pollutants are formed by the atmospheric transformation and most of the time they are associated with automotive emissions, NO_2 and hydrocarbons. Besides these gaseous forms (except SO_4^{2-} and NO_3^- -aerosols), pollutants are also present in the form of small particles known as Suspended Particulate Matter (SPM) in the atmosphere, expressing their effects on plants to varying extents.

1.2.3 The Primary Pollutants

1.2.3.1 Sulphur dioxide (SO_2)

The SO_2 is released in generation of electricity from coal and other fossil fuels, during roasting of ores and smelting operations (Gorham and Gordon, 1960; Wark and Warner, 1981). Sulphur which escapes in the process of sintering of the metal or heating of coal combines with oxygen at high temperature forms as SO_2. Sulphur in crude oil also escapes during the process of refining (Bailer **et al.**, 1973). SO_2 also escapes during the manufacture of sulphuric acid (Raman **et al.**, 1973). The increasing sources of SO_2 and its reported interaction with O_3, NO_x and fluoride make sulphur dioxide pollution as the most serious one (Bibbero and Young, 1974; Heck **et al.**, 1982).

Bleaching is the characteristic symptom of SO_2 and it may be irregular, bifacial, marginal or interveinal chlorosis and it may be associated with necrotic areas. It also includes slight yellow in the marginal areas at the beginning which progresses towards the middle of leaf blade turning the middle of the leaf blade to yellow and marginal areas to dry up (Heck and Brandt, 1977; Valenzona **et al.**, 1978).

At low concentrations, whether SO_2 can have an adverse effect on agricultural productivity has been debated for many years. Wislicenus (1901) and Stocklasa (1923) have suggested (quoted by Black, 1982) that plant yields could be depressed by low concentrations of SO_2 in the absence of visible injury. In contrast, Katz (1949) concluded that there was no evidence to support this concept of "invisible injury". Further, it has been reported that yield losses in SO_2-fumigated wheat and soyabeans were found only when visible damage had occurred (Brisley and Jones, 1950; Davis, 1972). It is suggested that when sulphur status of the soil is poor, low concentrations of SO_2 may act as a plant nutrient and improve the yield of some forest ecosystems (Smith, 1975) and agricultural crops (Cowling and Lockyer, 1978). The majority of recent reports, however , have suggested that SO_2 may indeed reduce several components of growth and yield in a range of species; these components include dry matter production and tillering, number of spikelets, percentage ripened grains, relative growth rate, shoot dry weight, root : shoot ratio, mean tiller weight and leaf area (Taniyama, 1972; Taniyama **et al.**, 1972; Bell and Clough, 1973; Lockyer **et al.**, 1976; Ashenden 1978 , 1979 ; Bell **et al.**, 1979; Crittenden and Read, 1979; Ayazloo **et al.**, 1980; Davies, 1980; Baker **et al.**, 1987). Though it has proved difficult to define the magnitude of these SO_2-induced effects on growth and yield of major agricultural crops, numerous attempts to define and elucidate these SO_2-induced changes in physiological processes highlighted the complexity and lack of mechanistic understanding of these responses (Mudd, 1975; Hällgren, 1978; Srivastava, 1978; Heath, 1980; Black, 1982). Clearly, it has been observed that any reduction in growth or yield must reflect the interference of the pollutants with cellular metabolism, carbon dioxide exchange or water loss.

1.2.3.2 Oxides of Nitrogen (NO_x)

Nitrogen oxides are formed like sulphur oxides, mainly as a result of the burning of fossil fuels. There is, however, little nitrogen in the fuel, and nitric oxide is formed during the combustion processes with high temperatures when atmospheric nitrogen and oxygen combine. There is then a spontaneous reaction between nitric oxide and oxygen to form nitrogen dioxide (Law and Mansfield, 1982). The major source of NO_2 are all high temperature combusion processes. Oxides of nitrogen emitted by vehicle exhausts are rapidly converted to NO_2 (Wark and Warner, 1981). Nevertheless the balance between NO and NO_2 in the atmosphere is variable and often unknown, which is why it is more convenient to refer to this form of pollution as NO_x.

Visible or acute injury may take the form of chlorotic areas appearing on the affected leaves, frequently associated with necrotic areas. These symptoms are often mistaken for the effects of other agents of which the grower is more aware, such as nutrient deficiency or sunscorch (Law and Mansfield, 1982).

Taylor and Eaton (1966) showed that continued fumigation with nitrogen dioxide reduces growth of tomato. Some investigations provided illustrations of growth reductions unaccompanied by visible markings (Bell and Clough, 1973; Ashenden and Mansfield, 1978). Spierings (1971) found that exposure of tomato to 250 ppb NO_2 throughout the growing period decreased the crop yield by 22 %. Apart from the known harmful effects of nitrogen oxides upon the growth and yield of plants there are considerable evidences at biochemical or **physiological** levels for the mechanisms by which they act.

1.2.3.3. <u>Ammonia</u>

Ammonia is often found in industrial atmospheres, especially in the vicinity of synthetic fertilizer factories, at levels similar to those of SO_2 and

NO_2 (Harrison and McCartney, 1979). Natural sources, feedlots are the additional sources other than nitrogenous fertilizer factories.

Ammonia gas is of intermediate toxicity to plants. The pattern of injury is different from that caused by other gases. Nearly all parts of the leaf assumed "a cooked green appearance becoming brown upon drying". Slight marginal injury alone was sometimes observed. The variegated leaves of coleus, "lost their brilliant colour", appearing green thereafter (Thomas, 1951). Accidental release of ammonia affected plants showed interveinal necrosis, sometimes localized at the leaf margin, as an acute effect or marginal necrosis progressing inwards between the larger veins. For some plant species the necrotic flecks were bordered by a reddish-brown to violet red margin. Subacute effects found to be silvering and bleaching, reddish-brown and violet discolourations and bronzing (De Temmerman, 1982).

Seeds when incubated under NH_3 (50% by volume in air) found that germination was totally and irreversibly inhibited in various members of Gramineae such as wheat, rice and rye (Siegel and Giumarro, 1965). However, the presence of 10 to 25 % NH_3 increased the germination of **Allium** cultivars moderately to markedly (Siegel and Daly, 1966). The effects of ammonia also attributed to the reduction in growth and productivity of plants such as **Trigonella, Crotalaria, Abelmoschar** and **Cyamopsis** (Chaphekar, 1972; Chaphekar and Boralkar, 1979). Damage to blackgram was also observed under ammonia fumigation (Raza and Bano, 1981).

1.2.3.4. Fluoride

Fluoride occurs in a wide range of natural materials such as coal, clay and mineral ores, and may be released when these are heated or burned at high temperatures. The major potential industrial sources of fluoride emissions are coal-burning power stations, aluminium smelters, phosphate fertilizer factories, and glass, brick and tile factories.

Fluoride injury is often characterised by tip burn of leaves. Hitchcock **et al.**, (1962) reported 10 years' work (1951-1960) on various effects of fluoride on **Gladiolus** associated with tip burns.

Murray (1981) worked around an aluminium smelter suggested that there is a common reaction of forest ecosystems to a local environmental stress which consists of a systematic dissection of strata, with decreasing distance the trees are eliminated first, then taller shrubs, lower shrubs, then herbs and finally bryophytes are removed. Associated with these changes in plant structure and reduced species diversity are parallel changes in animal populations, reduced biomass, energy fixation and nutrient cycling. Numerous observations with complemented experiments as reviewed by Bonte (1982) have enabled to show that for fluoride there exists a direct mode of actions on the process of fruiting. It has been demonstrated that for certain species the only sensitive period is flowering time. During that phase, fluoride appears to affect the female part of the flower, more precisely the stigma, from where significant amounts of fluorides have been measured.

1.2.4 The Secondary Pollutants

In areas of high motor-traffic density, intense sunlight and stagnant air, the primary pollutants released from exhausts (unburned hydrocarbons, oxides of nitrogen) are photochemically converted to an array of new compounds. The principal components of the oxidants in this mixture are ozone and the peroxyacy nitrates, the secondary pollutants (Mudd, 1982). Ozone is also being generated through electrical storms.

The minimal visible changes attributable, to ozone injury are necrosis, chlorosis, and/or flecking of the upper leaf surface. Ozone causes more injury (up to 75 per cent of the injury from all pollutants) to vegetation than any other pollutants (National Academy of Science, 1977). Growth and yield of soyabean cultivars are found to be affected by O_3 exposure (Heagle **et al.**, 1983).

1.2.5 Air Pollution Mixtures

Many sources of air pollution emit as a combination of two or more major pollutants and therefore the plants under field conditions in such areas are exposed not to a single but to a mixture of pollutants. The effects of mixtures of air pollutants on plants were largely unknown until Menser and Heggestad, 1966 reported that sublethal concentrations of SO_2 and O_3 produced an ozone type foliar injury in tobacco, greater than the additive effects of individual pollutants. Tingey and Reinert, (1975) while discussing the plant response to pollutant combinations have noted that the effects would be lesser than additive (antagonistic interference), greater than additive (synergistic, potentiate) or equal to additive effects of the individual pollutants.

Interaction of pollutants, leading to synergism or antagonism, may have a basis in biochemistry or physiology or both. Biochemical changes may be mitigated by additional protective mechanisms within the cell (Wellburn **et al.**, 1976). Recent reviews enlisted some of the interactions of the mixtures (Ormrod, 1982; Reinert, 1984). Many mixture effects seem to be species-dependent (Tingey and Reinert, 1975) and studies are therefore needed for each major crop species.

1.3.0 Physiological and Biochemical Changes to Air Pollution

Once the pollutants are absorbed by the plants, they are dissolved in the cell water of mesophyll cells to form various species of the pollutants, SO_2 thus dissolved in water to form H^+ , HSO_3^- and SO_3^{2-} ions, the latter being oxidised to SO_4^{2-} which then accumulates as the main product of SO_2 treatment. When NO and NO_2 dissolve in the extracellular water within a leaf, they form nitrate and nitrite ions. Uptake of ammonium ions leads to the production of H^+ ions, and fluoride leads to F^- ions. An effect of these ions on even one process at any level of organization within the cell may trigger a variety of subsequent effects and interactions to influence carbon fixation, growth and yield.

Several reports have been putforth about the injurious aspects of these pollutants expressed by the altered physiological and biochemical responses (Taylor **et al.**, 1961; Dugger **et al.**, 1963; Hill and Littlefield, 1969; Evans and Miller, 1979; Ziegler, 1973; Tingey **et al.**, 1975; Jaeger and Klein, 1980;

Tingey and Taylor, 1982; Koziol, 1984). On the basis of perspectives, the plant response may be viewed as the culmination of a sequence of biochemical and physiological events, beginning with pollutants uptake and ending with injury. Tingey and Taylor (1982) proposed a conceptual model for ozone injury with four sequential components as leaf conductance (gas and liquid phases), perturbation, homeostasis (recovery process) and injury. The same events can be applicable for all pollutants.

1.3 Leaf Pigments

Within the living cells, membranes in general, and among the cell organelleles the chloroplasts, are the first targets for air pollutants such as SO_2, as indicated at the ultrastructural and metabolic level (Jaeger and Klein, 1980). Reports of decreased chlorophyll concentrations in plants fumigated with SO_2, O_3 and HF and increased concentrations in plants fumigated with NO_2 were listed by Horsman and Wellburn (1976). Mueller (1957) found a preferential degradation of chlorophyll 'a' over chlorophyll 'b' in seedlings of common silver fir (**Abies alba**) exposed to SO_2, and he suggested that the change in ratio of these two forms could be used specifically to determine the effects of acid gases. Although lethal doses of SO_2 result in the breakdown of chlorophyll into phaeophytin and Mg in lichens (Rao and LeBlanc, 1966), this effect did not seem to occur **in vivo** with realistic SO_2 concentrations (Arndt, 1971). Arndt (1971) suggested the use of β carotene concentrations as an early reliable indication of injury from SO_2, HF and HCl fumigations. Measurements of changes in reflectance and transmission charcteristics of leaves were found to be useful for the assessments of chronic or mildly acute injury from air pollutants where the diffuse nature of the injury precludes a visual assessment (Runeckles and Resh, 1975).

1.3.2 Enzymes Activity

There are numerous reports in literature on the changes in enzymes activity associated with fumigation episodes (Horsman and Wellburn, 1976; Haellgren, 1978). The first enzyme which was used as an indicator of pollutant stress was polyphenol oxidase (Godzik, 1967). Peroxidase activity had been claimed to be a sensitive assay in plants as an indicator under variety of pollutants exposure such as SO_2, NO_2, flourides, ozone and traffic exhaust (Curtis and Howell, 1971 ; Horsman and Wellburn, 1975; Keller, 1974). Effects of air pollutants on nitrate reductase, nitrite reductase, glutamate dehydrogenase, glutamine synthetase were discussed by Wellburn (1982).

1.3.3 Endogenous Metabolites

Changes in the levels of free amino acids in response to fumigations with SO_2, O_3 and SO_2 + HF were observed by number of authors (Jaeger and Grill, 1975; Horsman and Wellburn, 1976, Malhotra and Sarkar, 1979; Pierre and Queiroz, 1981). Pribe **et al.**, (1978) reported an increased level of most amino acids and polyamines. Under SO_2 pollution the protein levels found to be affected as an indicator (Rabi and Kreeb, 1979; Sardi, 1981). Jaeger and Klein (1980) discussed the protein metabolism at the level of DNA and RNA in SO_2 - polluted plants. The level of ascorbic acid contents under air pollution were implicated as an attempt to indicate tolerance nature (Keller and

Schwager, 1977; Varshney and Varshney, 1984). The osmotic protectants - free proline and quaternary ammonium compounds were found to be accumulated under saline stress (Stewart and Lee, 1974; Wyn Jones **et al.**, 1977) and their information under pollution stress warrants investigation. Under stress conditions fluctuations of the thiol/disulfide status of the plant cell was not appeared to be tolerable as important functions such as protein synthesis, the catalytic activities of major proteins, and detoxification phenomena were highly susceptible to even minor changes in the thiol concentration such as glutatione.

The effects of gaseous pollutants on certain biochemical pathways would lead to the alterations in carbohydrate and amino acid pools, which would alter the balance of source/sink relationships between organs and lead to a shortage of assimilates in the growing region (Koziol and Jordon, 1978). In this connection, energy may be channelled preferentially into repair mechanisms, rather than to growth and development (Wellburn **et al.**,1976) and to other energy requiring process such as nitrogen fixation. In the process of detoxification of acid pollutants such as SO_2, the buffering capacity of the cellular fluids are depleted. Jaeger and Klein (1977) suggested that finding the changes in the buffering capacity of tissues exposed to gaseous pollutants as useful diagnostic test.

1.4.0 Strategies to Mitigate or to Avoid Air Pollution Injury

It would be unfortunate to see a substantial loss in agricultural production by the crops become more sensitive to injury from air pollution. Three general approaches viz., use of cultural practices, chemical protectants, and resistant varieties have been taken in the past to control or ameliorate the damage caused by air pollutants (Kender and Forsline, 1983). Environmental factors including humidity, light intensity, day length, and temperature influence plant response to air pollutants (Ormrod and Adedipe, 1974), however, they are generally difficult to control under field conditions. On the other hand, the edaphic factors which alter the physiological status of the plant may be easily modified by soil moisture, mineral nutrition and plant water balance. It is observed that SO_2 injury can be modified by nitrogen nutrition in tobacco (Leone and Brennan, 1972) and **Lolium perenne** (Ayazloo **et al.,** 1980). In addition, there are reports that water stressed tomato (Khatamian **et al.,** 1973) and tobacco (Mac dowell, 1965) are less sensitive to air pollutants due to the induction of stomatal closure by water stress which in turn modulates the effect of gaseous pollutants (Bell, 1980).

1.5.0 Air Pollution Problems

1.5.1 At Global Level

The emissions of air pollution at global level are either anthropogenic or natural. The pollutant gases are not restricted to a particular country or continent, for instance, to Europe or North America, but are characteristic of the atmosphere over these and other industrialized countries. The problem of sulphur dioxide and nitrogen oxides, annual emissions in North America and Western Europe together amount to about 50×10^6 tonnes of SO_2 and 30×10^6 tonnes of NO_x, in comparison to global emissions of pollutants which amounts about 60×10^6 tonnes (natural emissions of NO_x, have not been quantified). It is clear that the air chemistry of sulphur and nitrogen oxides is strongly influenced by anthropogenic emissions in North America and Western Europe (Fowler and Cape, 1982). Studies on world climate by World Meteorological Organization for 1980-81 reveals an increase of 15% carbon dioxide in the present century. It is increasing every year by 0.4%.

The protective ozone layer of the stratosphere is endangered by supersonic jets. The engine of these air-craft flying at high altitude release nitrogen oxides which catalytically destroy ozone molecules. In 1982, British Antarctic Survey, working at Halley Bay noticed a hole in the ozone layer over Antartica. This tenuous layer of gas is an essential part of the 'life support system' of the planet Earth. Without the ozone layer it is doubtful that there would be any life on land (Gribbin, 1988).

1.5.2 At National Level

India, emerging first among the developing countries in the industrial development, is also facing numerous problems of air pollution. It is estimated that 10% of our population living in slums, proximity of residential areas to polluting industries without proper control and heavily overloaded transport vehicles and old badly maintained automobiles contribute to a definite pattern of air pollution. This indicates a deterioration in the quality of air (Dave, 1986). A summary of air quality over a few selected Indian cities is given in Table 1. The levels of SO_2 and NO_2 in the air over the Indian cities are found to be below the international and national standards except in two cities, namely Baroda and Calcutta where the level has exceeded the international standard of 60 $\mu g/m^3$. But, it is well within the official CBPCP Indian Standard of 120 $\mu g/m^3$ (Dave, 1986).

Table : 1 Air quality over selected Indian cities - Annual average (24 h). All values are in µg/m³ (Dave, 1986).

Sr. No.	City	Parameter	1978 - 1982 5 year average
01.	Ahmedabad	SPM	249.27
		SO_2	41.57
		NO_2	25.67
02.	Bombay	SPM	190.60
		SO_2	38.34
		NO_2	19.88
03.	Calcutta	SPM	430.58
		SO_2	53.26
		NO_2	26.76
04.	Delhi	SPM	400.88
		SO_2	31.14
		NO_2	31.06
05.	Madras	SPM	143.34
		SO_2	13.32
		NO_2	12.60
06.	Baroda *	SPM	316.90
		SO_2	14.20
		NO_2	37.90

* = two years data.

Industries are contributing ample amount of pollutants to air. For example, Indian Fertilizer industry occupies the 4th position in the nitrogenous fertilizer production in the world. The installed fertilizer capacity during 1950 was 37,200 tonnes. The estimated projections by 1989/1990 for production of nitrogenous and phosphate fertilizers will be 9.88 and 2.56 million tonnes, respectively. Such an impressive growth also has its side effect namely the environmental pollution as given in Table 2 (Badrinath **et al.**, 1987).

Table : 2 Estimated Atmospheric Pollutants from Fertilizer Industry (Badrinath **et al.**, 1987).

Pollutant	Atmospheric emission	
	mg/sec	tn/day
SO_2	1,95,800	16.92
Particulate Matter	1,01,800	8.88
Ammonia	2,22,200	1.92
Urea dust	92,400	8.16

1.5.3 At Regional Level

The city Baroda which lies between 22°0' and 22°30' N latitude of 35 m above MSL, 390 km north of Bombay in the State of Gujarat has been facing pollution problems since late seventies. The automobile traffic in the city has increased manifold on its narrow roads, where the exhausts from the vehicles find no way to escape. This may facilitate the formation of secondary pollutants during summer times. Baroda, with a population of a million has the country's single largest concentration of petrochemical industries on its periphery. The petrochemical complexes include state owned units like Indian Oil Corporation's

Koyali Refinery, one of the biggest in Asia, Indian Petrochemical Corporation Ltd. (IPCL), Gujarat Alkali and Chemicals Ltd.,(GACL), and the Atomic Energy Commission's HWP. Besides, there are many private chemical companies, large and small, and about 500 other medium and small industries in the industrial estate of Nandesari. The present industrial status of Baroda is as under :

	Type of Industries	Number
01.	Chemical and Pharmaceutical	313
02.	Engineering and Electronics	740
03.	Glass, Rubber and Ceramics	52
04.	Plastic	105
05.	Packaging	42
06.	Paints	17
07.	Furniture	48
08.	Textile	14
09.	Optical	75
10.	Allied	205

(Source : Baroda Industrial and Trade Services).

The emission of pollutants from the industries affect the trees, crops and vegetation. Already the GSFC is quietly paying several lakhs of rupees, every year, to the farmers in its surrounding region, after the assessment of crops lost due to air pollution. IPCL had to pay Rs.28 lakhs for resettlement of 1000 odd inhabitants of Dhanora, a tiny village outside Baroda, as compensation for the crop lost (Anonymous, 1986 b).

Turning towards the otherside, by the early seventies the impacts of the pollutants on the environment were recognised and in 1973, at the request of the State Town Planning Department, Government of Gujarat, National Institute of Occupational Health (NIOH) - Ahmedabad had demarcated the air pollution zone and was marked on the map of Vadodara (Baroda) Urban Development Authority (VUDA) Area (Patel **et al.,** 1986). Subsequently between 1982 and 1985 NIOH had again made an integrated Air Quality Survey by the initiation of VUDA and various other agencies and again the zones of air pollution were identified by monitoring SO_2, NO_x and SPM in the ambient air (Patel **et al.,** 1986). The zones are depicted in Fig. 1. Earlier reports about the effects of air pollutants on plants around the industrial areas of northern Baroda show an extensive damage to the vegetation, particularly to crop plants (Patel and Bedi, 1977; Patel **et al.,** 1987). The abatement measures to control air pollution at the sources are restricted by economic, political and technical implications beyond the control of most agriculturists. So they are committed to grow their crops in an atmosphere containing certain levels of ambient pollutants. Further, the decreasing area of agricultural lands due to the expanding horizons of urbanization and industrialization needs a compensation by making the best use of the fertile lands for cultivation. Since, rice is the major source of calories for 40% of World's population (De Datta, 1981) it is desirable to investigate them in the polluted environment. Thus, this study has been designed and carried out to provide an insight to resolve the difficult problem of cultivation in the polluted environment with the following objectives :

1. To monitor the growth and yield of rice cultivars (genotypes with different degree of sensitivity) to chronic air pollution by modifying the soil nitrogen and water management.

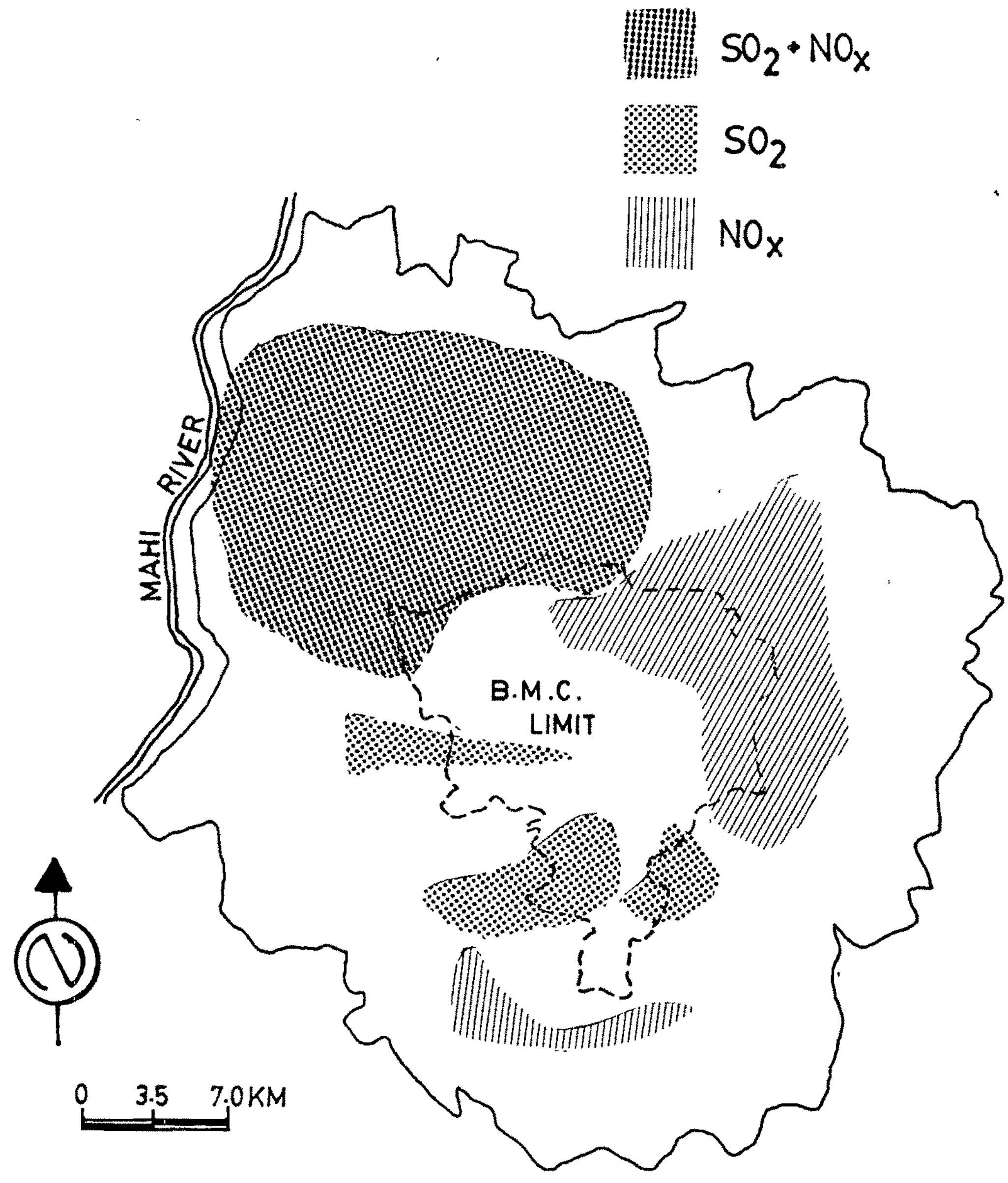

FIG:1. IMPLICATIONS OF SOURCES ON AIR QUALITY OF BARODA CITY SHOWING POCKETS OF SO_2 AND NO_x CONTOURS DEVELOPED BY DEC 1091 COMPUTER SYSTEM [Drawn from Patel et al., 1986 & Patel et al., 1987].

2. Use of growth promoters and antioxidant on rice plants to mitigate or to avoid air pollution injury.

3. To test the tolerance nature of a cultivar to air pollution for a subsequent generation.

4. Attempts to understand the physiological and biochemical mechanisms involved in the said conditions.

5. To conduct laboratory fumigation experiments with selected concentrations of SO_2, NH_3 and NO_2 singly and in combinations which would permit the application of ambient air exposure study-results in a wider context.

6. Ultimately to suggest the implications of the study to the farmers and scientific community.