EFFECT OF AIR POLLUTION ON VEGETATION: A REVIEW

[1]Pawan Chouhan, [2]Jagrati Solanki ,[2]Ruchika Purohit,[2]Pragya bohra[3]Dr. Anil Vyas,[4]Dr. S. K. Singh

[1]Post Graduate Scholar, Civil Engineering, MBM Engineering College, Jodhpur, India
[2] Post Graduate Scholar, Civil Engineering, MBM Engineering College, Jodhpur, India
[2] Post Graduate Scholar, Civil Engineering, MBM Engineering College, Jodhpur, India
[2] Post Graduate Scholar, Civil Engineering, MBM Engineering College, Jodhpur, India
[3]Professor, Chemical Engineering, MBM Engineering College, Jodhpur, India
[4]Professor, Civil Engineering, MBM Engineering College, Jodhpur, India
Corresponding author email:[1]251994pc@gmail.com

ABSTRACT: An environment plays a vital role for the sustainability of life on our planet. Environmental comprises some very basic parameters on which earth's life is very much dependent i.e. air, water and soil etc. Every parameter has got its own importance but air and water are two such thing without which human life can never be imagined .Further, water can be made usable by providing some degree of treatment but if air gets polluted to alarming level then ,it will not be so easy to adverse this effect. Air pollution receives one of the prime concern in India, primarily due to rapid economic growth, industrialization and urbanization with associatedincrease in energy demands. Lacks of implementation of environmental regulations are contributing to the bad air quality of most of the Indian cities. Air pollutants produced in any air shed are not completely confined, but at time trespassing all the geographical boundaries, hence do not remain only a problem of urban centres, but spread and affect remote rural areas supporting large productive agricultural land. Air pollutants pose risks on yield of crops depending on the emission pattern, atmospheric transport, leaf uptake and have a deleterious effect on a variety of biochemical and physiological processes and on structural organization within the cells.

Air pollutants have been shown to reduce the growth and yield before any visible symptoms appeared. It is now commonly believed that injury initially takes place at the biochemical level (interference with photosynthesis, respiration, lipid and protein biosynthesis, etc.), subsequently progressing to the ultrastructural level (disorganization of cellular membranes), and then to the cellular level (cell-wall, mesophyll, and nuclear breakdown). Finally, visible symptoms develop (chlorosis and necrosis of foliar tissues). An adverse effect caused by air pollutants depends not only upon its concentration, but also on the duration and combination of air pollutants. Biochemical injury results when the concentration of the pollutant exceeds the capacity of the tissues to detoxify it through their normal metabolism. The subtle and varied nature of the biochemical and physiological effects produced by air pollutants suggest that reduction in plant growth and yield.

Keywords: Air pollution, injury,SO_2, NO_2, CO,plant physiology.

I. INTRODUCTION

Air pollution is a major problem today not only in india but in the whole world. Air pollution adversaly affecting the various constituent of the environment. The main air pollutants are represented by gases forms, particles in suspension, different ionizing radiation.The gases forms are: oxidized and reduced forms of carbon (CO_2, CO, CH_4), of nitrogen (NO_2, NO, N_2O_4, NH_3, NH_4^+), SO_2, O_3, C_6H_6 vapours, Hg, volatile phenols, Cl_2, etc.The particulate forms are: PM10 and PM2.5 particulate matter, heavy metals with toxic effect (Pb, Ni, Cd, As), PAHs(polycyclic aromatic hydrocarbons) etc.

Air pollution was earlier considered as a local problem around large point sources. But due to use of tall stacks and long range transport of pollutants, it has become a regional problem. The transboundary nature of pollutants was clearly evident when areas remote from sources of air pollution also showed higher concentrations of air pollutants. Uncontrolled use of fossil fuels in industries and transport sectors has led to the increase in concentrations of gaseous pollutants such as SO_2, NOx, etc.

Effects of different kinds of pollution can be determined by the nature of pollutants, their concentration and the period of exposure. Under exposure to high concentration, plants suffer acute injury with externally visible symptoms, such as chlorosis, discolouration, necrosis and death of entire plant. Besides morphological changes, chemical, biochemical, physiological and fine structural changes also occur in plants.
Air pollution decreases the yield of all crops by affecting their photosynthetic activity and growth. Pollution damage can also be recognized by the accumulation of toxic material in the plant, changes in pH followed by solubilization of toxic salts of metals like aluminum, reduced or increased activity of certain enzymes, increase in compounds with SH groups and phenols, lowered ascorbic acid level in the leaves, depression of photosynthesis, stimulation of respiration, low dry matter production, changes in permeability, disturbances in water balance and reduced fertility under prolonged exposure. Plants show reduced productivity and yield and quality is lowered and ultimately they die. The symptoms of pollution affected plants are varied and unspecific. A particular pollutant affects different plants in very different ways and a particular symptom can be produced by a variety of substances. The development and severity of the injury depends not only on the concentration of the particular pollutant, but also on a number of other factors. These include the length of exposure to the pollutant, the influence of external factors (pollutants) on plants depends upon the species, stage of development and the organ and tissue involved as well as the environmental factors conducive to a build-up of the pollutant and to the preconditioning of the plant, which make it either susceptible or resistant to injury. Morphological alteration of a plant and floristic composition of a plant community are commonly used to indicate

changes in the environment. . The particulate matters have a negative mechanical effect. They cover the leaf blade reducing light penetration and blocking the opening of stomata. These impediments influence strongly the process of photosynthesis which rate declines sharply.
Among the biochemical aspects, the most important parameter is pigment analysis. Chlorophyll have been measured as index of response to different types of pollutionChemical estimation like proteins, amino acids, soluble sugars, sucrose, starch, reducing sugars, vitamin C, riboflavin, thiamine and carbohydrate are used to indicate foliar sensitivity to air pollution. Physiological activities as opening of stomata and rate of photosynthesis can also be used as indicator of pollution. Photosynthesis as a parameter has been used for mixed exposure to SO_2, NO_2 and dust. Enzymatic parameters are also used to indicate the presence of particular pollutant. Thus on the basis of enzyme activity, the susceptible species of plants can be identified. Other common enzymatic parameters used are ribulose diphosphate carboxylase, glutamate-pyruvate transaminase, glutamate- oxaloacetate transammase etc.

The chemical composition of the atmosphere is being altered/changed by the addition of gases, particulates and volatiles substances, which may be toxic to living beings. The levels of air pollutants are rapidly increasing in urban, periurban and rural areas in many megacities of the developing world. The adverse effects of air pollution have been associated with three major sources: sulphur dioxide and solid particulates from fossil fuels; photochemical oxidants and carbon monoxide from motor vehicles and miscellaneous pollutants such as hydrogen sulphide, lead and cadmium emitted by smelters, refineries, manufacturing plants and vehicles. Increased numbers of motor vehicles, power generation, domestic fuel use, refuse burning and other miscellaneous sources contribute to the problem of urban air pollution in India. Air pollution can be analysed on three spatial scales: global pollution, regional pollution and local pollutants.

The global pollution is the result of cumulative effects of various sources, located on the entire surface of the globe, manifested by global effects: the stratospheric ozone depletion; greenhouse effect - emission of greenhouse gases (CO_2, methane, CFCs, etc.); formation of aerosols (pollutant clouds which suspended particles and chemical compounds).

The regional pollution is in part the result of local air pollution-including that produced by individual sources, such as automobiles - that has spread out to encompass areas of many thousands of square kilometres. Meteorological conditions and landforms can greatly influence air-pollution concentrations at any given place, especially locally and regionally. For example, cities located in bowls or valleys over which atmospheric inversions form and act as imperfect lids are especially likely to suffer from incidences of severe smog. Oxides of sulfur and nitrogen carried long distances by the atmosphere and then precipitated in solution as acid rain, can cause serious damage to vegetation, waterways, and buildings.

The local pollutants (smog) can be loosely defined as a multi-source, widespread air pollution that occurs in the air of cities. Smog, a contraction of the words smoke and fog, has been caused throughout recorded history by water condensing on smoke particles, usually from burning coal.

Table 1:. Type of pollutants, origin and effect

Name of pollutants	Origin	Effects
Natural sources		
sulfur, chlorine, and ash particulates, smoke and carbon monoxide methane volatile organic compounds (VOCs) Aerosol from deforestation and burning: CO, CO_2, NO, NO_2, N_2O, NH_4	Volcanoes, wildfires, cattle and other animals, pine trees	-Acid rain - smog - respiratory irritant - increased respiratory - diseases - damage cell membranes of plants The effects are high only for volcanoes.
Anthropic sources		
Carbon monoxide, carbon dioxide, sulphur dioxide, nitrogen oxides, fluorides and substances with fluorine,chlorine (Cl_2), bromine (Br_2) and iodine (I_2), small dust particles, VOC, methane, ammonia and radioactive radiation.	Industry: the mining industry, oil and natural gas extraction, the energy industry based on fossil fuels - coal, oil, natural gas, the production of brick, tile, enamel frit, ceramics, and glass; the manufacture of aluminium and steel; and the production of hydrofluoric acid, phosphate chemicals and fertilizers. central heating,chemical and metallurgical industry, engineering internal combustion machinery industry, industrial waste, noises	- respiratory irritant - acid rain - smog - increased respiratory - formation of secondary pollutants (PAN, O_3) - effect on soil fertilizer - Respiratory diseases - toxic effects on living cells - greenhouse gas effect - toxic effects - carcinogenic proprieties - accumulation in tissues - blocking of different processes
CO, CO_2, NO, NO_2, NH_3, CH_4, SO_2, oxides of heavy metals, H_2SO_4, SPM, HC, VOC, background aerosols: sea salt oxidation of sulphur containing	Agriculture: the vegetation fire, the denitrification process, in soils excessively fertilized and excessive use the pesticides ,	formation of secondary pollutants (PAN, O_3) - effect on soil fertilizer - respiratory diseases - greenhouse gas effect

gases, same organics, nitrous oxide (N_2O) pesticides	paddy field, intensive husbandry, deforestation	- toxic effects - acid rain - stratospheric ozone depletion
Aerosols from transport and constructions NOx, CO, HCl, Lead and other heavy metals , SPM	The motor vehicle pollution, noises	- smog - increased respiratory diseases - damage cell membranes of plants - carcinogenic proprieties - accumulation in tissues - blocking of different processes - stratospheric ozone depletion
Domestic aerosols CFC, HC, FC, H_2S, CH_4 CO_2	sewage plans, authorized landfill site	carcinogenic proprieties - accumulation in tissues - blocking of different processes - stratospheric ozone depletion

1.1 Structure of a Leaf

Leaves enable photosynthesis to occur. Photosynthesis is the process by which leaves absorb light and carbon dioxide to produce carbohydrate (food) for plants to grow. Leaves are adapted to perform their function, eg they have a large surface area to absorb sunlight.

Plants have two different types of 'transport' tissue, xylem and phloem, that move substances in and around the plant. When water evaporates from the leaves, resulting in more water being drawn up from the roots, it is called transpiration.

The equation for photosynthesis is:

Carbondioxide and water → glucose and oxygen

Table 2 : Features of leaves.

Adaption	Purpose
Large surface area	To absorb more light
Thin	Short distance for carbon dioxide to diffuse into leaf cells
Chlorophyll	Absorbs sunlight to transfer energy into chemicals
Network of veins	To support the leaf and transport water and carbohydrates
Stomata	Allow carbon dioxide to diffuse into the leaf

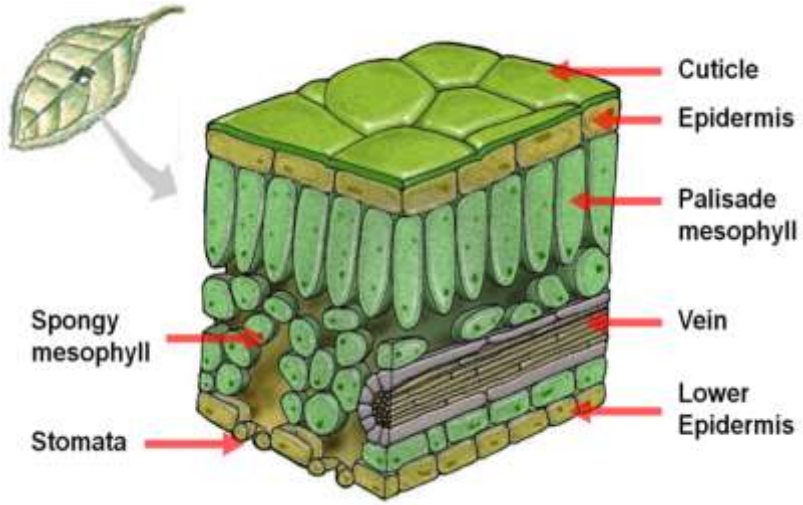

Fig. 1: Transverse Section of Typical Leaf

II.DAMAGE THEORY

The air pollutants currently considered to be most important in causing direct damage to vegetation are $S0_2$, NOx, O_3 , F and SPM. Direct effects of air pollution can be further classified into visible and invisible injury. Visible injury normally takes the form of discolouration's of the leaf surface caused by internal cellular damage. Such injury can reduce the market value of agricultural crops for which visual appearance is important (e.g tobacco and spinach). It can also lead to yield reductions, while the damaged parts of the leaf surface can provide points of entry for plant pathogens. Invisible injury results from pollutant impacts on plant physiological or bioche mical processes and can lead to significant loss of growth or yield and changes in nutritional quality (e.g. protein content).Visible injury tends to be associated with short-term exposures to high pollutant levels whilst invisible injury is generally a consequence of longer-term exposures to moderately elevated pollution concentrations.

Leaves are most susceptible parts of a plant to acute injury due to their abundance of stomata, which permit penetration of the pollutants into the sensitive tissues. The first barrier of gaseous air pollutant is boundary layer resistance which varies with wind speed and size, shape and orientation of leaves.At higher wind speed, boundary layer resistance declines allowing more pollutant entry into the leaf. The cells most

exposed to air pollutant action are epidermal cells, but waxy cuticle is a potential barrier to most of the pollutant gases. However, acidic gases can dissociate and react with cuticular waxes and enter leaves by penetrating through damaged cuticle.

Dust pollution is of localized importance near roads, quarries, cement works, and other industrial areas. Apart from screening out sunlight, dust on leaves blocks stomata and lowers their conductance to CO_2, simultaneously interfering with photosystem. Polluting gases such as SO_2 and NOx enter leaves through stomata, following the same diffusion pathway as CO_2. NOx dissolves in cells and gives rise to nitrite ions (NO_2^-, which are toxic at high concentrations) and nitrate ions (NO_3^-) that enter into nitrogen metabolism as if they had been absorbed through the roots. In some cases, exposure to pollutant gases, particularly SO_2, causes stomatal closure, which protects the leaf against further entry of the pollutant but also curtails photosynthesis. In the cells, SO_2 dissolves to give bisulfite and sulfite ions; sulfite is toxic, but at low concentrations it is metabolized by chloroplasts to sulfate, which is not toxic. At sufficiently low concentrations, bisulfite and sulfite are effectively detoxified by plants, and SO_2 air pollution then provides a sulfur source for the plant. In urban areas these polluting gases may be present in such high concentrations that they cannot be detoxified rapidly enough to avoid injury. Ozone is presently considered to be the most damaging phytotoxic air pollutant in india. It has been estimated that wherever the mean daily O_3 concentration reaches 40, 50, or 60 ppb (parts per billion or per 10^9), the combined yields of soybean, maize, winter wheat, and cotton would be decreased by 5, 10, and 16%, respectively. Ozone is highly reactive: It binds to plasma membranes and it alters metabolism. As a result, stomatal apertures are poorly regulated, chloroplast thylakoid membranes are damaged, rubisco is degraded, and photosynthesis is inhibited.

2.1. FACTORS INFLUENCING AIR POLLUTION DAMAGE TO VEGETATION.

Damage in isolated areas occurs when pollutants are spread long distances by wind currents. Factors that govern the extent of damage and the region where air pollution is a problem are

1. type and concentration of pollutants.
2. distance from the source.
3. length of exposure.
4. Meteorological conditions.

For some pollutants, damage can occur at levels below Environmental Protection Agency standards. Other important factors are city size and location, land topography, soil moisture and nutrient supply, maturity of plant tissues, time of year, and species and variety of plants. A soil moisture deficit or extremes of temperature, humidity, and light often alter a plant's response to an air pollutant. Damage caused by air pollution is usually most severe during warm, clear, still, humid weather when barometric pressure is high. Toxicants accumulate near the earth's surface when warm air aloft traps cooler air at ground level. This is called air inversion.

2.2. TYPES OF DAMAGE TO VEGETATION & EVALUATION OF SYMPTOMS

In addition to killing plants, atmospheric pollutants adversely affect plants in various ways. Pollution injury is most commonly classed as acute, chronic (chlorotic), or hidden. In acute injury collapsed marginal or intercostal leaf areas are noted which at first have a water-soaked appearance.Later these dry and bleach to an ivory color in most species, but in some they become brown or brownish red. These lesions are caused by absorption of enough gas to kill the tissue. Chronic injury involves leaf yellowing which may progress slowly through stages of bleaching until most of the chlorophyll and carotenoids are destroyed and interveinal portions of the leaf are nearly white. Chronic injury is caused by absorption of an amount of gas that is somewhat insufficient to cause acute injury or it may be caused by absorption over a long period of time of sublethal amounts of gas.

The histological changes most commonly noted in pollution-injured leaves include plasmolysis, granulation or disorganization of cell contents, cell collapse or disintegration, and pigmentation of affected tissue. Sometimes the physiological activity of affected plants is impaired before any external symptoms are visible. For this reason many investigators referred to "hidden," "invisible," or "physiological" injury of pollutants.

2.3. TYPES, CONCENTRATION& EXPOSURE OF POLLUTANTS AND DAMAGE ON VEGETATION.

Table 3: Different types of pollutant, theirsource and effect on vegetation.

Pollutants	Sources	Effects on Vegetables
Aldehydes	Photochemical reactions	The upper portions of Alfalfa etc. will be affected to Narcosis if 250 ppm of aldehydes is present for 2 hrs duration.
Ozone (O3)	Photochemical reaction of hydrocarbon and nitrogen oxides from fuel combustion, refuse burning, and evaporation from petroleum products.	All ages of tobacco leaves, beans, grapes, pine, pumpkins and potato are affected. Fleck, stipple, bleaching, bleached spotting, pigmentation, growth suppression, and early abscission are the effects.
Peroxy Acetyl Nitrate (PAN)	The sources of PAN are the same as ozone	Young spongy cells of plants are affected if 0.01 ppm of PAN is present in the ambient air for more than 6 hrs.
Nitrogen dioxide (NO2)	High temperature combustion of coal, oil, gas, and gasoline in power plants and internal combustion engines.	Irregular,white or brown collapsed lesion on intercostals tissue and near leaf margin. Suppressed growth is observed in many plants.
Ammonia & Sulfur dioxide	Thermal power plants, oil and petroleum refineries.	Bleached spots, bleached areas between veins, bleached margins, chlorosis, growth suppression, early abscission, and reduction in yield and tissue collapse occur.

Chlorine (Cl2)	Leaks in chlorine storage tanks, hydrochloric acid mists.	If 0.10ppm is present for at least 2hrs, the epidermis and mesophyll of plants will be affected.
Hydrogen fluoride, Silicon tetrafluoride	Phosphate rock processing, aluminum industry, and ceramic works and fiberglass manufacturing.	Epidermis and mesophyll of grapes, large seed fruits, pines and fluorosis in animals occur if 0.001 ppm of HF is present for 5 weeks.
Pesticides & Herbicides	Agricultural operations	Defoliation, dwarfing, curling, twisting, growth reduction and killing of plants may occur.
Particulates	Cement industries, thermal power plants, blasting, crushing and processing industries.	Affects quality of plants, reduces vigor & hardness and interferences with photosynthesis due to plugging leaf stomata and blocking of light.
Mercury (Hg)	Processing of mercury containing ores, burning of coal and oil.	Greenhouse crops, and floral parts of all vegetations are affected; abscission and growth reduction occur in most of the plants.

Fig. 2: Acute sulfur dioxide injury to raspberry.

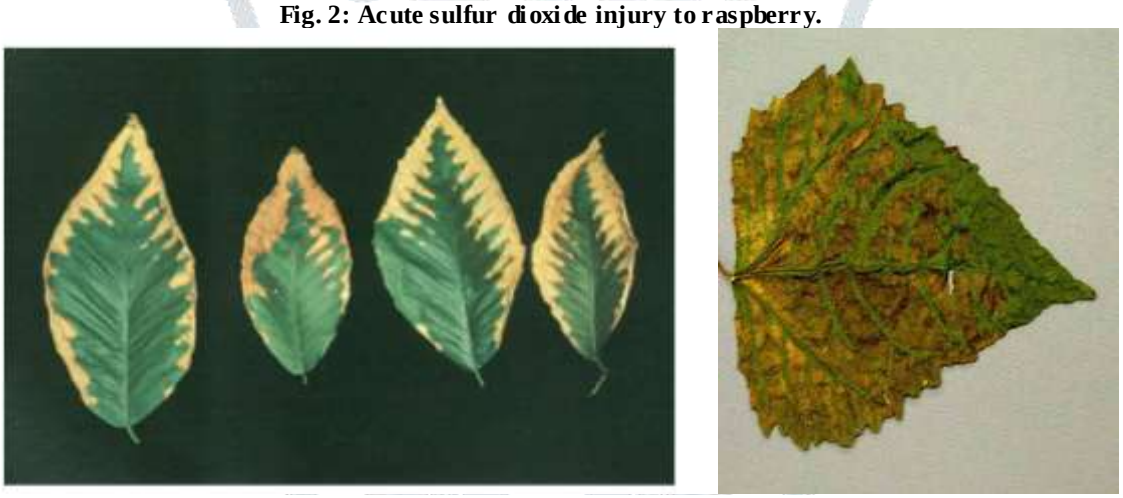

Fig.3: Marginal and interveinal necrosis on American beech leaves exposed to sulfur dioxide

Fig.4: Yellowish mottle and marginal chlorosis on sweetgum leaf exposed to F.

Fig.5: Dark, reddish pigmentation on dogwood leaves exposed to sulfur dioxide

Fig. 6: Leaf tissue appear bleached by chlorine from the air.

Fig. 7: Dry sepal damage of Cattleya orchid due to atmospheric ethylene.

Fig. 8: Silvering Of spinach leaves caused by smog.

Fig. 9: Bleaching of upper surface of watermelon leaves exposed to ozone

Fig. 10: Tipburn on eastern white pine exposed to ozone.

Fig. 11: Peroxyacetyl Nitrate (PAN) creates a glazy bronzing on the underside of newly expanded potato leaves.

III.MODEL FOR GASEOUS POLLUTANT SORPTION BY LEAVES

During the growing season, plants may be important sinks for some air pollutants. While certain pollutants can be readily sorbed by plants, however, others are taken up much less effectively. Pollutant uptake by plants is controlled by the interaction of a number of physical, chemical, and biological factors that regulate gas transfer processes and pollutant reaction at the sorbing sites. A knowledge of the factors and interrelationships involved is requisite for proper understanding of the process. The model was designed to isolate and emphasize: (i) important factors regulating pollutant transfer, and (ii) effects of specific pollutant and leaf properties on the uptake process.The model is based on an electrical analogue simulation principle. Electrical analogue models have been used extensively by previous authors to describe gas and energy exchange with leaves.

IV.CONCLUSION

Air pollution is a major problem today not only in india but in the whole world. Air pollution is a complex mixture of local, urban and regional source. Air pollution decreases the yield of all crops, reduced productivity and plant quality is lowered and ultimately they die by affecting their photosynthetic activity and growth. Pollution damage can also be recognized by the accumulation of toxic material in the plant, changes in pH followed by solubilisation of toxic salts of metals like aluminium. Effects of different kinds of pollution can be determined by the nature of pollutants, their concentration and the period of exposure. Under exposure to high concentration, plants suffer acute injury with externally visible symptoms, such as chlorosis, discolouration, necrosis and death of entire plant. Besides morphological changes, chemical, biochemical, physiological and fine structural changes also occur in plants. Different parameter is used to identify the damage coused by air pollutant on vegetation and to understand plant response aginst the aior pollutant. In biochemical aspects, the most important parameter is pigment analysis. Chlorophyll have been measured as index of response to different types of pollution Chemical estimation like proteins, amino acids, soluble sugars, sucrose starch, reducing sugars, vitamin C, riboflavin, thiamine and carbohydrate are used to indicate foliar sensitivity to air pollution. Physiological activities as opening of stomata and rate of photosynthesis can also be used as indicator of pollution. Photosynthesis as a parameter has been used for mixed exposure to SO_2, NO_2 and dust. Enzymatic parameters are also used to indicate the presence of particular pollutant. Thus on the basis of enzyme activity, the susceptible species of plants can be identified.Other common enzymatic parameters used are ribulose diphosphate carboxylase, glutamate-pyruvate transaminase, glutamate-oxaloacetate transammase etc.

Plant responses to air pollution are helpful in the following ways:

- **a)** Establishing the early presence of air-borne contaminants.
- **b)** Determining the geographical distribution of the pollutants.
- **c)** Estimating the concentration of pollutants.
- **d)** Providing a passive system for collecting pollutants for chemical analyses later.
- **e)** Obtaining direct identification of different air pollutants on the basis of plant species and variety affected.

Recommendations & future needs :

- **a)** Expand air pollutant monitoring networks into agricultural and forested areas.
- **b)** Need to establish yield response relationships applicable to different environmental conditions to project future yield losses at increasing ozone concentrations .

c) Develop bio-indicator protocols for impact evaluation.
d) Interactive effects of increased concentrations of CO_2 and O_3 on plants along with temperature(drought).
e) Establish realistic air quality guidelines for protecting vegetation including crops – CAgM.

REFERENCES

[1] Ainsworth EA, A Rogers, ADB Leakey. Targets for crop biotechnology in a future high-CO_2 and high-O_3 world - Plant Physiology, 147: 13-19,2008.
[2] Robert A. O'Dell , Mansoor Taheri & Robert L. Kabel (1977) A Model for Uptake of Pollutants by Vegetation, Journal of the Air Pollution Control Association, 27:11, 1104-1109, DOI: 10.1080/00022470.1977.10470533
[3] Bell, JNB and M Treshow, Cinchester John Wiley & Sons, Air Pollution and Plant Life. 2008.
[4] Booker, FL, R Muntifering, M McGrath, KO Burkey, D Decoteau, EL Fiscus, W Manning, S Krupa, A Chappelka, DA Grantz. 2009. The ozone component of global change: Potential effects on agricultural and horticultural plant yield, product quality and interactions with invasive species Journal of Integrative Plant Biology. 51:337-351.
[5] United States Environmental Protection Agency (EPA) Report.
[6] www.cleartheair.nsw.gov.au (www.icp-forests.org). The Impact of Air Pollution on Health, Economy, Environment and Agricultural Sources.
[7] www.icp-forests.org/Reports.htm.
[8] www.cleartheair.nsw.gov.au/science_an.
[9] www.windows2universe.org/milagro/effects/wildlife_forests.html.
[10] Dugger, W. M., Jr., and Ting, I. P. (1970b). Physiological and biochemical effect of air pollution oxidants on plants. Recent Advan. Phytochem. 3, 31-58.