
Responses of plant metabolism on air pollution and climate in Sindh, Pakistan

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Introduction

The major part of Pakistan is dominated by dry climate. A small area in the north have sub-tropical climate. The subtropical location of Pakistan from approximately 23 N° to 37N° latitudes tends to keep the temperature high particularly in summer. In Pakistan air pollution is reported in Karachi, Hyderabad, Lahore, Faisalabad, Gujranwals, Sialkot. Rawalpindi and Peshwar, the oceanic influence of Arabian Sea keep down the temperature contrast between summer and winter at the cost. A temperature inversion layer at low elevation of approximately 1500 meters (5,000 feet) in the southern part of Pakistan during the summer season does not allow the moisture – laden air to raise and condensation to take place.

The environmental problems in Pakistan have emanate from three sources:

Nature

- Topographic and climatic constrains.
- Floods.
- Desertification and earthquakes.

Man made interaction

- Population growth and resources.
- Salinity and water-logging.
- Soil erosion and soil toxicity.

Man made

- Urban growth.
- Air pollution.
- Water pollution .
- Solid Waste.

Air pollution

The various reason of air pollution is as under:

- The air pollution caused by automobiles planes other form of transportation and various industry smokes.
- The widespread and indiscriminate pesticide application in Pakistan have some time caused contamination of the environment an some disastrous ecological damage.
- The increase in the green house gases which are reported for the year 1988 was CO₂ increase, by 15% and CH₄ of 150%

- The photochemical pollutant which stabilize either as nitrates or as CO₂ and water, normally the global emission of 33,528 nt/day of nitrous oxides, which means a yearly atmospheric increase of 2×10^6 ppm.
- The main phytotoxic component of smog is peroxyacetyl nitrate (PAN)
- The substance responsible for air pollution are "Fossil" fuel, combustion, carbon dioxide, carbon monoxide, unburned hydrocarbons, oxides of nitrogen, sulfur dioxide and smoke and the results of compound produce due to reaction like Peroxyacetyl Nitrates (PAN) and other oxidants and its concentration normally is about 310 ppm and produce ill effects when it reaches to 5,000ppm
- The rapid industrialization and urbanization bring air pollution and environmental degradation. The major sources of air pollution are industries like petrochemicals, fertilizers, synthetic fibers, metallurgy, sulfuric acid, nitric acid, pharmaceutical chemicals and ceramic, industries. Also automobiles emit large quantities of carbon monoxide hydrocarbons, oxides of nitrogen and other pollutants. The air pollution shows ill effect on growth of vegetation including crop and forest cover.

Air pollution chart

- Deposited matters.
- Dust and grit
- Shoot and smoke (produce by the iron and steel foundries)
- Sulfur dioxide (produce by non-ferrous smelters)
- Fluorine and fluoride produce by steel mills, ammonia and phosphate fertilizer industries.
- Photochemical smog (produce nitrogen oxides)
- Ozone
- Peroxyacetyl nitrates like Peroxyacetyl nitrate (PAN)
- Oxides of nitrogen (Nitric acid plant)
- Ethylene
- Aldehydes.
- Heavy metals like iron , lead, beryllium, arsenic, mercury, chromium.
- Hydrogen sulfide (produce by cement plant)
- Hydrogen chloride (Caustic and chloride plants)
- Asbestos fibrous (and possibly other fibers of critical size)
- Carbon dioxide (as a potential modifiers of climate)
- Chlorofluro carbon.

Air pollutant which effect on vegetation are as under

- Sulfur dioxides
- Oxidants
- Hydrocarbons
- Hydrogen sulfide
- Fluorides

- Lead
- Beryllium
- Hydrogen chloride
- Chlorine
- Arsenic
- Mercury
- Chromium
- Aldehyde
- Carbon monoxide
- Hydrocarbon
- Ozone.

Air pollution not only cause visible symptoms in the living things but it also produce invisible symptoms, such as in case of plants approximately 50% growth and production is effected by air pollution. Due to air pollution thermal factors exert a deep influence on vital activities of plants.

Air pollution which cause damage to plants, often resulting in scorching systems of the leaves, young mature, old leaves, stem and blossoms escape injury except from massive doses of pollutant. Some plants immediately response to air pollution. We call them as indicator plants, which include certain crop plants and weeds show immediately symptoms in response to air pollution. Such crops and weeds utilize as an indicator to know air pollution.

The oat act as an indicator, while as injure to bronzing and glazing the lower surface of the leaves of beans and tomatoes. The air pollution results in to destruction of protein compound within the plant tissues. Air pollution is injurious to plant metabolism. The air pollution effects on plant are as under.

Mild injury, called chlorotic phase, in this phase only veins, leaf tissue become yellow, and acute or chlortic phase. In this phase leaf turns to brown and not able to photosynthesis and dead at the end.

Photochemical air pollution appear to be fungi toxic and black spot of roses, caused by diplocarpon rosac resulted with air contain more than 100mg of sulfur dioxide per cubic meter show microsphaera all phitodes (oak milden several conifer results including;)

- Melampsora Cerastii (Melamsorella caryophllacearum)
- Puccinia graminis (Black rust of cereals)
- Air pollution bring phytotoxicity in the plants. The air pollution symptom generally appears on the leaves, bring indefinite browning, necrosis, eventually shedding.
- The principal phytotoxic substances in polluted air as ethylene cause epinasty and leaf abscission, hydrogen fluoride marginal and apical browning and necrosis of leaves, leading to lateral margins and nitrogen dioxide (leaf bleaching), ozone (stripling mottling and chlorosis or leaves) Sulfur dioxide (interveinal chlorosis).Dust from cement plants is injurious to fruit trees because it my settle on the floral parts and disturb the fruit formation.

Effect of heavy metal on plants

Lead

Molecular Pb²⁺ more stable than PbCl₂. Pb found to be effective mucous of clad formation, causing fine mist and diminishing incident solar radiation.

Lead effect on plant

Lead is absorbed by foliage and retained by the cell membrane and mitochondria.

Cadmium

The wear of car tires produce cadmium dust, which enter in to the air and gasoline also contain traces of cadmium.

Copper

Copper pollution may bring enzymatic activity changes in the plants,

Mercury.

Mercury may enter the leaf tissue. Plants both inhale and exhale gaseous Hg through the stomata HgCl₂ found in broccoli, carrot, potato, lettuce and beans. Mercury vapors damage the leaves of lettuce and carrot. Translocation of Hg occurs in many plant tissue like apple, tubers and potatoes. Contamination from mine flue gases and resulting Hg accumulation in plant tissue especially note in carrot, onion, potato and beet.

Effect of air pollutant gases on plants

Fluoride

Fluoride injury

Industrial plants producing aluminum, steel, ceramics, phosphorus, chemicals and fertilizers, produce fluorine fumes. Fluorine gas can easily absorb by the plants through its leaves and concentrated in the tips and margins. Even the low concentration for a long period of time effect on crops.

Indicator crops are as under:

- Gladiolus.
- Corn
- Apricot
- European grape

Pollutant fluoride compounds are result of high temperature or acid treatment of materials that contain fluoride, such as manufacture of fertilizers ceramics and some metals. The contaminant may be gasses or small particulate in character.

Fluoride's are toxic to plants, they enter the plants through stomata and migrate to the periphery of the leaves. The leaf may absorb fluoride and eventually accumulate lethal amounts of the material at the leaf edge. The eaves then die from margins inwards, the dried margins of the leaves Hydro fluorite acid produces small spots and turns the tips of gladioli leaves white .The different plants show different reaction level with fluoride. Apricot and peach trees are susceptible to fluoride, while corn and sweet of susceptible species such as Dracaena and Gladiolus.

Nitrogen compound

The polluting nitrogen compounds are nitrogen oxides. Nitrogen oxide is a production of combustion at extraordinarily high temperature of under great pressure electrical power plants and automobile. Nitrogen gas is yellow brown in color and produce smell, when dense, can be fatal at the concentration of 1 to 3 ppm The other pollutant compound is nitric acid. This corrosive formaldehyde and nitrous oxide (NO) is oxidize to NO₂ and provide further source of reactant .No₂ (nitrogen dioxide) its concentration at 8-10 ppm is toxic. Nitrous oxide concentration 0.02 - 0.9 ppm is normal level and 3.00 ppm level in the air are toxic level. The nitrogen oxide participate in photochemical reaction, which produce oxone and Peroxyacyl nitrates (PAN), which is highly phytotoxic oxidant. It effects the stippling and necrotic area on the upper leaf surface. Tobacco, lettuce and beans are the indicator plants.

Photochemical products

The smog consists of hydrocarbons and composed basically of hydrogen and carbon. it retards the growth and development of tomatoes of brazing of the lower leaves of plants. Lemon and grape fruit tree are especially susceptible Proxy peopyl nitrate, a common photochemical pollutant damage vegetables crops .Smog damage the crops.

Carbon compound

It pollutant is carbon-monoxide (CO), is a colorless and odorless, and eventually converts to carbon dioxide .In controlled green house condition. Scientist has found that in abundant carbon dioxide plant grow more rapidly, the size of lettuce and tomatoes increased. Vitamin C and sugar content in tomatoes rise, resistance to virus disease, parasitic fungi and insects increase and up to 30,000 ppm not proved lethal.

Sulfur dioxide

The power plants are smelters release large quantity of Sulfur dioxide, which produce its effect up to 35 miles from the source. This gas converts to Sulfur in about one day. Some time results due to green house burners especially using paraffin. These gases damage the whole leaves and some time show reddish discoloration on the leaves.

Indicator plants

Response at 0.5 ppm for a few minutes, exposure, these crops are:

- Alfalfa
- Cotton
- Squash
- Melon

- Okra
- Zinnis
- Cockiebur
- Pigweed (Amaranthus)

SO₃ react with water to produce as aerosol form of sulfuric acid, which is toxic to plants at 0.2 ppm. Sulfur dioxide concentration at 3.2 ppm plant are injured at such levels. Sulfur dioxide and phosphates air pollutant harm plants, Some studies have indicated that the cost of this damage may be great as 500 Kronor per ton of SO₂ released in to the atmosphere.

Sulfur dioxide is considered to be one of the most serious pollutant of the atmosphere because of its sever effect on living plants. The gas is easily absorbed through the leaf stomata the tiny hole on the leaf surface through which the atmospheric gasses move in to and out of the inner leaf.

Visible symptoms of leaf injury in plant caused by Sulfur dioxide vary Dense concentration of SO₂ over short period damage tissue and turn the leaves to a pale white or in some cases, to dark red-brown color than the needless fall off. Injury to the plants leaves is due to transformation of which are deposited at the periphery of the leaves.

Low concentration of SO₂ over many days or weeks produce a characteristic chlorosis or yellowing, of the leaves. Frequently leaves than fall, and plant growth turn slow. Such chronic injury caused by the building of great amount of Sulfate in the leaf produce from absorbed SO₂

Plant varies in their susceptibility to SO₂ gas like: Alfalfa, cotton ,grape, squash is seriously effected by this pollutant. Sulfur dioxide also reacts with ozone and nitrogen dioxide to seriously affect some plants. Sulfuric acid droplets, falling on plant surface are harmful to plant tissue.

Ozone

The nitrogen dioxide, sulfur dioxide, aldehydes absorb ultraviolet radiation from the Sun and the resultant, Excited molecule easily react with molecular oxygen (O₂) frequently to yield atomic oxygen (O), So activated nitrogen dioxide (NO₂), Splits to form nitric oxide (NO) and atomic oxygen (O). Atomic oxygen react with molecular oxygen to form ozone (O₃) and with nitrogen oxide to reforms nitrogen dioxides a result of this oxidation reaction, ozone is produced abundantly.

Ozone can depletes the growth rate of plant without producing any obvious or visible lessons. Visible damage is known and occurs as leaf blotches, which disintegrate in very high concentration, it produces white marking on the leaves of certain grain crops, and produce "Tip burns "Old and young leaves are easily affected than mature leaves.

Ozone is colorless gaseous form of oxygen and odor like chlorine. This result form photochemical process involving ultraviolet radiation. The ozone absorb ultraviolet (2000-3000 Angstroms) and produce healing effect up to 50Km range, ozone even in small concentration is a poisonous gas.

Indicator plants are under:

- Spinach
- Bean
- Alfalafa
- Oats
- Apple
- Sycamore.

Ozone produce stippled chlorotic or bronzed spot on the upper surface of the leaves. Ozone itself formed by photochemical action of ultraviolet light on exhaust fumes and can reach a sufficient concentration to be phytotoxic

The ozone and Peroxyacetyl nitrate both photochemical produce phytotoxicants, adversely effect the semi permeability of the cellular membrane possibly by reacting with the lipids of cell membranes and also reducing the ability of the plant to repair the damage. These two pollutants are also reported to reduce photosynthesis to change chloroplasts and interfere with amino acids and enzymes, particularly those depend on sulphhydryl group for their activity (Discussed by Duggar and Tign 1970)

Ozone first symptoms are water soaked spot, followed by chlorosis along or between the veins and eventually necrosis and drying up of affected leaves which may shed.

Effect of climatic change on agriculture

The climatic change will bring many changes in the plant phenomena like processes of growth (cell division and cell expection) which operate down stream from photosynthesis and are themselves sensitive to climatic control also change in the reproductive phase of seed or spore production.

The climatic changes on agriculture are as under:

- Change in mean crop yield
- Change in the variability of yields
- Non-linear effects
- Effect on regional and national food production
- Change in crop variety.
- The reproductive performance of vegetation and may bring geographical spread at the Northern extremity of the distribution to Southern, and reduction in the contribution of bryophytes to the biomass of grassland and woodlands.

Air pollution effect on plant metabolism

General

For all metabolic activity in the plant, we usually consider three main processes, which are used for this purpose are photosynthesis, this process takes place in the chloroplast of the plants. Photo respiration, take place in chloroplast peroxisome and mitochondria of the cell membrane, while respiration takes place in the cytoplasm and mitochondria of the cell membrane

The most of air pollutant effect on the surface of the leaves, and disturb the tissue and break the cell membrane activity, also reduce photosynthesis chloroplast, while disturbing the following normal function of the tissue.

Tissue and cell types and their functions

Tissue system	Tissues	Major functions
Dermal	Epidermis Periderm	Regulation of size of stomata and hence rate of water loss and oxygen and dioxide exchange Support, protection
Ground	Parenchyma Collenchyma Sclerenchyma	Photosynthesis, storage, support , secretion Photosynthesis Support, protection
Vascular	Xylem Phloem	Conduction of water and mineral nutrients. Conduction of sugar, organic nitrogen compounds and hormones in angiosperms

Nucleus

It determines the genetic properties of the cell and responsible for the transmission of hereditary characters from one cell to another and from parent to offspring. One day weight basis the nucleus has the following composition.

Nucleus composition	Percentage.
Protein	70%
DNA	10%
Phospholipids	3-5%
RNA	2-3%

The air pollutant disturbs the lipid, amino acid, RNA, DNA and protein and disturb the nucleus activities

Chloroplast

Chemical analysis indicate that the chloroplast are composed of protein (enzymes), Phospholipids, the green pigment chlorophyll and yellow pigments carotenoids. They also contain some ribonucleic acid (RNA), small amount of deoxyribonucleic (DNA) and ribosomes. A chloroplast has following average composition on the dry weight basis.

Chloroplast composition	Dry weight basis.
Protein	40-50%
Chlorophyll	5-10%
RNA	5%
Phospholipid	23-25%
Carotenoid	1-2%
DNA	Small amount

Most of air pollutant change the composition of chloroplast and reduce its activity.

Protoplasm

Protoplasm is a dynamic substance, the composition of which is continuously changing with the result that no two analyses give identical results. Plasmodium of mycomycetes is almost pure protoplasm and is the most suitable material for the study of chemical composition of protoplasm. Composition of protoplasm of protoplasm is percent of total wet weight.

Inorganic compounds	Total wet weight
Water	75-80%
Salts	0.1%
Organic compound	
Protein	10-20%
Lipid	2-3%
Carbohydrate	1%
DNA	0.4%
RNA	0.7%

The air pollutant changes the organic and inorganic contents in the protoplasm and bring some change in protoplasm activities.

Gloxyosomes and peroxisomes

They are cytoplasm microbodies, which are intermediate between mitochondria and microcosms. They contain "Catalase" enzyme, which take part in respiration. They are mostly concern with Glyoxalate cycle of respiration. Mitochondria do can also synthesis structural protein. The chemical composition of mitochondria on the dry weight basis is as follow:

Mitochondria chemical composition	Dry weight basis.
Protein	65-70%
RNA	0.5%
Phospholipid	25-30%
DNA	Small amount

The air pollutant disturbs the mitochondria and as a result the enzymes in the mitochondria will disturb as a result respiration and metabolic activities in the plant get altered or change.

Ribosome's

They are minute macromolecular granular particles, 100-50 A in diameter. They consist of ribonucleic protein, being made up of protein and ribonucleic acid (RNA) They are most abundant in cells, engaged in active protein synthesis.

Matrix

It contains amino acid, RNA, hydrolytic enzyme, those concern with anaerobic metabolism.

Sperosomes

These occur in the storage cells of plants. They contain hydrolyze and phosphates enzymes, ribonuclease, protease, esterase. They are concerned with the storage and transport of fats. Since the air pollutant disturb the activities of amino acid and protein, which ultimately effect on ribosome matrix and sphersome of the plants.

Enzyme

The living plants consist of various types of organic molecules. They are present in the protoplasm, mitochondria, ribosomes and chloroplasts or they are contained in the various cell structures like the membranes and chromosomes. These molecules a have been produced in the cell as a result of chemical reaction. The chemical reactions are exegetic or endergoic and combined reaction in the living organism is called metabolism.

The metabolic reaction occur and the way they are interlined are all depend upon the occurrence and efficient working of enzymes. The specificity of enzymes is due to their primary amino acid sequences. Which get disturbed due to air pollutants.

Enzymes are produced in the protoplasm's . They act as catalysts, speed up the chemical reaction. Enzyme can act only upon a particular substrate or particular group of substrates and each kind of metabolic reaction is catalyses by a specific kind of enzyme. Some of trace element are the essential components of enzyme and act as their activators. The prosothetic group of simple kind is made up of single atom to some metals. Like Cu, Zn, Mo, Mg, Mn, K, Fe and certain oxidizing enzymes. Such enzymes called "Metallo enzymes".

Nitrate reduction and protein synthesis take place in green leaves. Sugar is produced in green plants by the process of photosynthesis. Also carbohydrates, protein, fat, essential oil, tannins, gum, mucilage are produced in the plant body.

The major enzymatic activity disturbing by environment

- Reversibility of enzymes action equal to , the equilibrium will be disturbed.
- Effect of enzyme on contrition, since the velocity of reaction is proportional to enzyme concentration.
- Effect of substrate concentration, the high substrate concentration will inhibit the enzyme activity.
- Product inhibition of enzyme activity, if the product of enzyme reaction accumulate, the result some time is the inhibition of enzymatic activity.
- Sensitivity of enzyme, enzyme are sensitive to heat, rise in temperature, acid, alkali's, certain salts. Each enzyme, act best in a certain hydrogen-ion-concentration (pH). Which is peculiar to its activity, any change will effect the activity of enzyme.

Isoenzymes

Some times an enzyme is present in more than one form. Such different form of enzymes called isoenzymes. Air pollution effect the activity of enzyme, it automatically effect the activity of isoenzymes.

Co-factors

The Co-factors are inorganic ions, which are essential for the function of enzymes, e.g. their normal function is as under:

- The co-factors are inorganic ions, which are essential for the function of enzymes, like their normal function is as under:
- CL is a co-factor for α -amylase, which catalyses the hydrolysis of starch to maltose
- Mg. Cofactor for enzyme, which use catalyses the transfer of phosphate group to and from adenosine phosphates
- Cofactor ions, Zinc, manganese, magnesium, iron, copper, molybdenum.
- Iron + copper, needed for oxidation reaction.
- Co-enzyme, those organic molecules for protoplasm, which participate in and enzyme catalyses reaction. The air pollution disturbs the co-factor activity and as a result changes in complete reaction.

Co-enzymes

Co-enzymes or co-dehydrogenase is important and participate in metabolic reaction in which oxidation of substrate molecule is brought about by specific enzymes by removing hydrogen, thus coenzyme consumed in one metabolic reaction and converted in to another substance is regrettet in some subsequent reaction. Many of water-soluble vitamins of the B complex group are the components of molecules of several co-enzymes their activities are also disturbed due to air pollution.

Digestion

The digestion takes place in the green leaves of the plant, starch synthesized in the green leaves, then starch is converted in to soluble sugar, and transported to growing embryo or sprouting buds at the time of germination of seed or store in storage organs like seed and tubers. The air pollutant disturbs the digestion system and break the starch synthesis.

Golgi-er-lysosome

Golgi complex contain large amount of digestive enzyme "acid phosphates ".This enzyme move to lysosomes along with hydrolytic enzymes. Air pollutant effect on the amino acids, lipid and protein as a result the permeability of membrane also gets destroyed.

The following respiratory enzymes disturbed due to air pollution.

1) Oxidoreductases

- a) Oxidases
- b) Peroxidases
- c) Oxygenase

2) Transphosphorylases

- a) Hexokinase
- b) Phosphohexokinase
- c) Phosphoglyceric-trans phosphorylase
- d) Phosphopyruvate-transphosphorylase

3) Phosphorylases**4) Demolases****5) Hydrases**

Following hydrolytic plant enzymatic activity disturbed due to air pollution.

1) Carbohydrates

- a) Amylase
- b) Cellulose
- c) Cytase
- d) Insulase
- e) Sucrose (Invertase)
- f) Maltose
- g) Lactose
- h) Emulsion
- i) Cellobiasses

2) Esterases

- a) Lipase
- b) Chlorophylase
- c) Pectase
- d) Phosphatases
- e) Phosphorylases
- f) Glucosan phosphorylase
- g) Sucrose phosphorylase

3) Enzymes hydrolyzing nitrogen compounds.

Protease

- Reepsinsases
- Trypsinases
- Papatinases

Peptidases (Erypsinatases)

The enzymes involved in activation energies get disturbed due to air pollution.

Reactions

- 1) H_2O_2 , decomposition
- 2) Casine hydrolysis
- 3) Ethyl butyrate hydrolysis.

The following ATP-requiring reaction in plant disturbed.

- Synthesis of protein (including enzymes) from amino acids
- Synthesis of fat and lipids from glycerol and fatty acid
- Synthesis of cell walls from various sugars.
- Active uptake and extrusion of small molecules.
- Synthesis of sucrose form glucose and fructose.
- Synthesis of starch from glucose

Future

- We have to accurate predicted the level of pollution in the air and scientist must establish a model in which they will check the air pollution effect and its cure.
- Check the high level of CO_2 in the air enhancing the photosynthetic rate and water use efficiency in C_3 crop as a result of elevated CO_2 will compensate for some of negative effects, of high temperature and reduced eater availability.

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