A Review of Some Different Effects of Air Pollution on Plants

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INTRODUCTION

Air pollution is one of the severe problems world is facing today. It deteriorates ecological condition and can be defined as the fluctuation in any atmospheric constituent from the value that would have existed without human activity (Tripathi and Gautam, 2007). In recent past, air pollutants, responsible for vegetation injury and crop yield losses, are causing increased concern (Joshi and Swami, 2007). Urban air pollution is a serious problem in both developing and developed countries (Li, 2003). The increasing number of industries and automobile vehicles are continuously adding toxic gases and other substances to the environment (Jahan and Iqbal, 1992). All combustion release gases and particles into the air. These can include sulphur and nitrogen oxides, carbon monoxide and soot particles, as well as smaller quantities or toxic metals, organic molecules and radioactive isotope (Agbaire and Esiefarienrhe, 2009). Over the years, there has been a continuous increase in human population, road transportation, vehicular traffic and industries which has resulted in further increase in the concentration of gaseous and particulate pollutants (Joshi et al., 2009). Adverse effects of air pollution on biota and ecosystems have been demonstrated worldwide. Much experimental work has been conducted on the analysis of air pollutant effects on crops and vegetation at various levels ranging from biochemical to ecosystem levels. It has been observed that ozone concentrations are higher in suburban and rural areas as compared to the urban areas, whereas SO$_2$ and NO$_x$ concentrations are higher at urban sites (Tiwari et al., 2006).

Environmental stress, such as air pollution, is among the factors most limiting plan productivity and survivorship (Woo et al., 2007). It is a major problem arising mainly from industrialization. Pollutants could be classified as either primary or secondary. Pollutants that are pumped into the atmosphere and directly pollute the air are called primary pollutants while those that are formed in the air when primary pollutants react or interact are known as secondary pollutants (Agbaire, 2009). It has been observed that plants particularly growing in the urban areas affected greatly due to varieties of pollutants [oxides of nitrogen and sulphur, hydrocarbon, ozone, particulate matters, hydrogen fluoride, peroxyacetyl nitrites (PAN) etc.] (Jahan and Iqbal, 1992). Air pollution can directly affect plants via leaves or indirectly via soil acidification. When exposed to airborne pollutants, most plants experienced physiological changes before exhibiting visible damage to leaves (Liu and Ding, 2008). The atmospheric SO$_2$ adversely affects various morphological and physiological characteristics of plants. High soil moisture and high relative humidity aggravated SO$_2$ injury in plants (Tankha and Gupta, 1992). Industrialization and the automobiles are responsible for maximum amount of air pollutants and the crop plants are very sensitive to gaseous and particulate pollutions and these can be used as indicators of air pollution (Joshi et al., 2009). In urban environments, trees play an important role in improving air quality by taking up gases and particles (Woo and Je, 2006). Vegetation is an effective indicator of the overall impact of air.
pollution and the effect observed is a time-averaged result that is more reliable than the one obtained from direct determination of the pollutant in air over a short period. Although, a large number of trees and shrubs have been identified and used as dust filters to check the rising urban dust pollution level (Rai et al., 2010).

Plants provide an enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollutant level in the air environment, with a various extent for different species (Liu and Ding, 2008). The use of plants as monitors of air pollution has long been established as plants are the initial acceptors of air pollution. They act as the scavengers for many air borne particulates in the atmosphere (Joshi and Swami, 2009).

EFFECT ON LEAF MORPHOLOGY

Pollutants can cause leaf injury, stomatal damage, premature senescence, decrease photosynthetic activity, disturb membrane permeability and reduce growth and yield in sensitive plant species (Tiwari et al., 2006). Reductions in leaf area and leaf number may be due to decreased leaf production rate and enhanced senescence. The reduced leaf area result in reduced absorbed radiations and subsequently in reduced photosynthetic rate (Tiwari et al., 2006).

Dineva (2004) and Tiwari et al. (2006) recorded reduction of leaf area and petiole length under pollution stress conditions.

Previous researches reported significant reduction in different leaf variables in the polluted environment in comparison with clean atmosphere (Jahan and Iqbal, 1992). In their study on Platanus acerifolia showed changes in leaf blade and petiole size in the polluted air. Significant reduction in length and area of leaflets and length of petiole of G. officinale of polluted plants was recorded. Reduction in dimension of leaf blade of five tree species in the vicinity of heavy dust and SO₂ pollution was also observed (Jahan and Iqbal, 1992). Significant effects of automobile exhaust on the phenology, periodicity and productivity of roadside tree species was also reported (Bhatti and Iqbal, 1988). Decrease in leaf area in drought stress had been observed because tolerance of water content of tissue possible by decrease in leaf area (Hale et al., 1987).

Increase in length, breadth of leaflets and decrease in area of leaf had demonstrated in leaves of Albizia lebbeck under the stress of air pollution (Seyyednejad et al., 2009a, b). Moreover, study on leaves of Callistemon citrinus planted in industrial region clears that length, breadth of leaf and also leaf area decreased (Seyyednejad et al., 2009a, b). Effect of industrial air pollution on leaf morphology of Prosopis juliflora was investigated (Koochak and Seyyed Nejad, 2010). Cassia siamea plants growing at two different sites (polluted and non-polluted) on two important roads of Agra city exhibited significant differences in their flowering phenoology and floral morphology (Chauhan et al., 2004). Researchers showed that stimulation of photosynthetic rates in elevated CO₂ was nullified by decreased total leaf area (Noormets et al., 2001). Totally describe of air pollution is related to morphology of area of leaf visible damage including reduction of leaf area, changes in morphology as compare to unpolluted condition, necrosis and chlorosis (Heath, 1980). Naide and Chricot (2004) showed that by the effect of air pollutant exchange of gases on area of leaf of Avicenia marine decreased. One way to increase tolerance in contrast with stress is to balance the water content of tissue by decrease the leaf area (Hale et al., 1987). It seems that this species use this way as defense mechanism.

EFFECT ON THE PIGMENTS CONTENT

Air pollution stress leads to stomatal closure, which reduces CO₂ availability in leaves and inhibits carbon fixation. Net photosynthetic rate is a commonly used indicator of impact of
increased air pollutants on tree growth (Woo et al., 2007). Plants that are constantly exposed to environmental pollutants absorb, accumulate and integrate these pollutants into their systems. It reported that depending on their sensitivity level, plants show visible changes which would include alteration in the biochemical processes or accumulation of certain metabolites (Agbaire and Esiefarianrhe, 2009).

Sulphur dioxide (SO$_2$), nitrogen oxides (NO$_x$) and CO$_2$ as well as suspended particulate matter. These pollutants when absorbed by the leaves may cause a reduction in the concentration of photosynthetic pigments viz., chlorophyll and carotenoids, which directly affected to the plant productivity (Joshi and Swami, 2009).

A relationship between traffic density and photosynthetic activity, stomatal conductance, total chlorophyll content and leaf senescence has been reported (Honour et al., 2009). One of the most common impacts of air pollution is the gradual disappearance of chlorophyll and concomitant yellowing of leaves, which may be associated with a consequent decrease in the capacity for photosynthesis (Joshi and Swami, 2007). Chlorophyll is found in the chloroplasts of green plants and is called a photoreceptor. Chlorophyll itself is actually not a single molecule but a family of related molecules, designated as chlorophyll "a", "b", "c" and "d". Chlorophyll "a" is the molecule found in all plant cells and therefore its concentration is what is reported during chlorophyll analysis (Joshi et al., 2009). Chlorophyll is the principal photoreceptor in photosynthesis, the light-driven process in which carbon dioxide is "fixed" to yield carbohydrates and oxygen. When plants are exposed to the environmental pollution above the normal physiologically acceptable range, photosynthesis gets inactivated. The distribution of plant diversity is highly dependent on presence of air pollutants in the ambient air and sensitivity of the plants. Chlorophyll measurement is an important tool to evaluate the effects of air pollutants on plants as it plays an important role in plant metabolism and any reduction in chlorophyll content corresponds directly to plant growth (Joshi and Swami, 2009). Chlorophyll is an index of productivity of plant. Whereas certain pollutants increase the total chlorophyll content, others decrease it (Agbaire and Esiefarianrhe, 2009). Changes in concentration of pigments were also determined in leaves of six tree species exposed to air pollution due to vehicle emissions (Joshi and Swami, 2009).

The shading effects due to deposition of suspended particulate matter on the leaf surface might be responsible for this decrease in the concentration of chlorophyll in polluted area. It might clog the stomata thus interfering with the gaseous exchange, which leads to increase in leaf temperature which may consequently retard chlorophyll synthesis. Dusted or encrusted leaf surface is responsible for reduced photosynthesis and thereby causing reduction in chlorophyll content (Joshi and Swami, 2009). A considerable loss in total chlorophyll, in the leaves of plants exposed to pollution supports the argument that the chloroplast is the primary site of attack by air pollutants such as SO$_2$ and NO$_x$. Air pollutants make their entrance into the tissues through the stomata and cause partial denaturation of the chloroplast and decreases pigment contents in the cells of polluted leaves. High amount of gaseous SO$_2$ causes destruction of chlorophyll (Tripathi and Gautam, 2007). Several researches have recorded reduction in chlorophyll content under air pollution (Tiwari et al., 2006; Tripathi and Gautam, 2007; Joshi and Swami, 2007, 2009; Joshi et al., 2009). On the contrary, Several researches have exhibited increase in chlorophyll content under air pollution, such as Tripathi and Gautam (2007) reported that Mangifera indica leaves subjected to air pollution showed an increase (12.8%) in chlorophyll content (Tripathi and Gautam, 2007). Agbaire and Esiefarianrhe (2009) in a study have demonstrated that plants from experimental site contain more chlorophyll compared with those from the control.
Increase in content of chlorophyll a, chlorophyll b, total chlorophyll and carotenoid in *Albizia lebbeck* and *Callisemon citrinus*, has been reported by Seyyednejad *et al.* (2009a). Investigation proved that chlorosis, is the first indicator of flour effect on plant (Kendrick *et al.*, 1956). Yun (2007) showed reduction in photosynthesis because of the PSII function damage, in sensitive species of tobacco (Yun, 2007). Carotenoids exist in plasma of plant tissues, photosynthetic or non photosynthetic; the function of carotenoids in chloroplasts is as pigments to capture the light. But probably more important role is in protecting the cells and live organisms encounter with damage of free radical oxidative (Fleschin *et al.*, 2003). Plants fumigated with 40, 80 and 120 ppbv concentrations of O₃ exhibited significant reduction in total chlorophyll content, RuBP carboxylase activity and net photosynthesis (Chapla and Kamalakar, 2004).

Carotenoids protect photosynthetic organisms against potentially harmful photooxidative processes and are essential structural components of the photosynthetic antenna and reaction center (Joshi and Swami, 2009). Carotenoids are a class of natural fat-soluble pigments found principally in plants, algae and photosynthetic bacteria, where play a critical role in the photosynthetic process. They act as accessory pigments in higher plants. They are tougher than chlorophyll but much less efficient in light gathering, help the valuable but much fragile chlorophyll and protect chlorophyll from photooxidative destruction (Joshi *et al.*, 2009). Joshi and Swami (2007) showed among four plant species subjected to air pollution, highest decrease in carotenoid contents was reported for *Eucalyptus citroiodora*. Joshi and Swami (2009) also determined the concentration of carotenoids in the leaves of six tree species exposed to vehicular emission. They reported the reduction in concentration of carotenoids in the leaf samples collected from polluted sites (Joshi and Swami, 2009). Several researchers have reported reduced carotenoid content under air pollution (Joshi *et al.*, 2009; Tripathi and Gautam, 2007; Tiwari *et al.*, 2006).

**EFFECT ON SUGAR**

Soluble sugar is an important constituent and source of energy for all living organisms. Plants manufacture this organic substance during photosynthesis and breakdown during respiration (Tripathi and Gautam, 2007). Tripathi and Gautam (2007), in their study revealed significant loss of soluble sugar in all tested species at all polluted sites. The concentration of soluble sugars is indicative of the physiological activity of a plant and it determines the sensitivity of plants to air pollution. Reduction in soluble sugar content in polluted stations can be attributed to increased respiration and decreased CO₂ fixation because of chlorophyll deterioration. It has been mentioned that pollutants like SO₂, NO₂ and H₂S under hardening conditions can cause more depletion of soluble sugars in the leaves of plants grown in polluted area. The reaction of sulfite with aldehydes and ketones of carbohydrates can also cause reduction in carbohydrate content (Tripathi and Gautam, 2007).

Some researchers showed that Concentrations of total and soluble sugars decreased significantly in the sensitive trees to the air pollution. In damaged *Q. cerris* leaves the decrease in concentrations of sugars was higher in September. The decrease in total sugar content of damaged leaves probably corresponded with the photosynthetic inhibition or stimulation of respiration rate (Tzvetkova and Kolarov, 1996). Furthermore, increase in amount of soluble sugar is a protecting mechanism of leaves it has been shown in Pinto bean in exposure with different concentration of ozone (Dugger and Ting, 1970).

Following ozone exposure, soluble sugars in pine needle decreased (Wilkinson and Barnes, 1973). Subsequently they increased, frequently in association with foliar injury (Dugger and Ting,
The increase of soluble sugars was also observed following chronic exposure (Miller et al., 1969). The increase in soluble sugar was reported in Albizia lebbeck and Callistemon citrinus grown in industrial land (Seyyednejad et al., 2009a). Investigations revealed that the more resistant species plants to the air pollution as compare to sensitive species showed more concentration of soluble sugar (Kameli and Losel, 1993; Ludlow, 1993). Study on resistance of Dodonea viscosa and Prosopis juliflora to industrial air pollution were done and results showed increase in soluble sugar (Abedi et al., 2009a, b; Koochak and Seyyed Nejad, 2010).

EFFECT ON PROLINE

Some workers have published the increase in free proline content in response to various environmental stresses in plants (Levitt, 1972).

Thypical environmental stress (high and low temperature, drought, air and soil pollution) can cause excess Reactive Oxygen Species (ROS) in plant cells, which are extremely reactive and cytotoxic to all organisms (Pukacka and Pukacki, 2000). High exposure to air pollutants forces chloroplasts into an excessive excitation energy level, which in turn increases the generation of ROS and induces oxidative stress (Woo et al., 2007). The deleterious effects of the pollutants are caused by the production of Reactive Oxygen Species (ROS) in plants, which cause peroxidative destruction of cellular constituents (Tiwari et al., 2006). It has been reported that proline act as a free radical scavenger to protect plants away from damage by oxidative stress. Although, the scavenging reaction of ROS with other amino acids, such as tryptophan, tyrosine, histidine, etc. are more effective compared with proline, proline is of special interest because of its extensive accumulation in plants during environmental stress (Wang et al., 2009).

Tankha and Gupta (1992) showed the increase in content of proline with increasing SO₂ concentration. According to existence of SO₂ and CO in the industrial area as the result of chemical activities, these results probably indicate that it has been clearly inconceivable to designate a harmless threshold toxic SO₂ concentration for level of particular species since other environmental factors during pollution profoundly affect the degree of damage (Seyyednejad et al., 2009b).

Significant increase in content of proline in Albizia lebbeck grown in polluted area has been reported (Seyyednejad et al., 2009b) the concentration of proline increased in leaves of Callistemon citrinus planted round petrochemical site in comparison with control site (Seyyednejad et al., 2009b). Proline is a universal osmolytic accumulated in response to several stress and may have a role in plant defense reactions (Khattab, 2007). Obviously proline has main role in protection in different kinds of stress. Accumulation of proline in plants is a physiological response to osmotic stress (Szekely, 2004).

The effects of pollutants on plants include pigment destruction, depletion of cellular lipids and peroxidation of polyunsaturated fatty acid (Tiwari et al., 2006). There appears to be a relationship between lipid peroxidation and proline accumulation in plants subjected to diverse kinds of stress (Wang et al., 2009). If such a relationship exists, proline accumulation might play an important role in inhibiting air pollution-induced lipid peroxidation. Proline accumulation often occurs in a variety of plants in the present of different stresses. For example, proline accumulation in leaves of plants exposed to SO₂ fumigation (Tankha and Gupta, 1992), heavy metals (Wang et al., 2009) and salt (Woodward and Bennett, 2005) stress has been reported (Tankha and Gupta, 1992; Wang et al., 2009; Woodward and Bennett, 2005).

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REFERENCES


