International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(3): 1684-1688

Received: 18-03-2020
Accepted: 20-04-2020

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A Review of effects of air pollution on physical and biochemical characteristics of plants

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DOI: https://doi.org/10.22271/chemi.2020.v8.i3w.9442

Abstract
Air is the most important resource for sustenance of life and all organisms need clean air for their healthy growth and development. But today this air has become highly polluted due to industrialization and urbanization. Air pollutants are responsible for reduction of biological and physiological response of various plants and crops grown in polluted areas. Plants are an integral basis for all ecosystems and also most likely to be affected by air borne pollution which are identified as the organisms with most potential to receive impacts from ambient air pollution. This review reveals the impact of air pollution on physical and biochemical parameters of plants.

Keywords: Air pollution, ascorbic acid content, total chlorophyll content, pH, relative water content

1. Introduction

Air pollution is defined as introduction of foreign particles into the atmosphere in the form of chemicals, particulate matter or biological materials that cause harm or discomfort to human or other living organisms, or damage the environment. Uncontrolled use of fossil fuels in industries and transport sector further led to the increase in concentrations of gaseous pollutants (Kulkarni and Ingawale, 2014) [1]. Overexploitation of open spaces, ever increasing number of automobiles and demographic pressure has further aggravated the problem (Sharma and Roy, 1999) [2]. Since plants are stationary and continuously exposed to chemical pollutants from the surrounding atmosphere, air pollution injury to plants is proportional to the intensity of the pollution. The effects are most often apparent on the leaves which are usually the most abundant and most obvious primary receptors of large number of air pollutants. Plant leaves has been regarded as biofilters as they absorb large quantities of particles from the environment (CPCB, 2007) [3]. Plants act as the scavengers for air pollution as they are the initial acceptors of air pollution (Mahecha *et al*., 2013) [4]. Plants also act as air pollution sinks but the better performance comes from the pollution tolerant species (Miria and Khan, 2013) [5]. The ability of each plant species to absorb and adsorb pollutants by their foliar surface varies greatly and depends on several biochemical, physiological and morphological characteristics (Seyyednejad *et al*., 2011) [6]. After the release of pollutants into the atmosphere only plants can be helpful in adsorbing and metabolizing them from the atmosphere. Therefore, plants serve important role in reducing air pollution and also helps in improving the quality of air by taking up gases and particles (Horaginamani and Ravichandran, 2010) [7].

2. Effect on physical characteristics

Accumulation of dust particles (pollutants) depends on internodal distance, petiole length, leaf area, orientation, margin, folding and arrangement, hair density, hair type and length (Yan and Hui, 2008[8]; Escobedo *et al.*, 2008) [9]. Previous researches reported that leaf orientation, age, roughness and wettability of the leaf surface influences dust interception and retention (Beckett *et al*., 2000) [10]. Generally exposed areas of a plant especially leaves act as constant absorbers for particulate matters (Samal and Santra, 2002) [11]. Smaller plants with short petioles and rough leaf surfaces accumulate more dust than larger plants with long petioles and smoother leaf surfaces (Prusty *et al*., 2005) [12]. Adverse effects of urban air pollution on leaf architecture of plants has been demonstrated by Sher and Hussain (2006) [13]. Stevovic *et al.* (2010) [14] worked on Tansy plant and they reported that leaves from polluted site were significantly thinner than those from an unpolluted area.

Thick leaves showed lower deposition for all particle sizes, apart from 0.2 to 2.5 mm particles (Saebo *et al*., 2012) [15]. Researchers showed that plants exposed to pollution showed lower leaf area, petiole length as compared to plants growing in control site (Seyyednejad *et al*., 2013) [16]. Probability of deposition of air pollutants increase in surface area per unit volume of plants (Roupsard *et al*., 2013) [17]. Different types of leaves tend to have differences in several aspects of their surfaces. Some types of leaves have greater surface rigidity or roughness which may affect their stickiness or particle solubility. Stickier leaves are better for collecting particles because more particles would stick to their surface. Therefore, certain plant leaves may be more useful for efficient dust capturing than other plants (Kumar *et al*., 2013) [18]. Deposition of particulate matter on vegetation will be affected by the particle size distribution and the dimension and density of foliage elements in the dispersion path. Large leaved species may provide effective particulate matter barriers close to the source of particulate matter (e.g roads) but less effective barriers against finer particulate matter that travel greater distances (Rahul and Jain, 2014) [19]. Rai and Panda (2014b) [20] reported that foliar surface of plants is continuously exposed to the surrounding atmosphere and is, therefore, the main receptor of dust and this physical trait can be used to determine the level of dust in the surroundings as well as the ability of individual plant species to intercept and mitigate it. They further reported that plants with waxy coating, rough surface with folded margin accumulate more dust than plants with smooth, flat surface without folded margin. Kaler *et al*. (2016) [21] reported that dust accumulation capability of plants depends on their range of characteristics which include outside geometry, phyllotaxy and leaf attributes (cuticle and pubescence of leaves), tallness and canopy of plants.

3. Effect on biochemical characteristics

Plants that are constantly exposed to environment pollutants absorb, accumulate and integrate these pollutants into their system and depending on their sensitivity level, they show visible changes including alteration in the biochemical processes, accumulation of certain metabolites (Agbaire and Esiefarienrhe, 2009) [22]. Variation in the biochemical parameters in leaves is used as an indicator of air pollution for early diagnosis of stress or as a marker for physiological damage prior to the onset of visible injury symptoms (Tripathi *et al*., 2009) [23].

3.1 Effect on ascorbic acid content

Ascorbic acid is a strong reducer and plays important role in photosynthetic carbon fixation with the reducing power directly proportional to its concentration (Thakar and Mishra, 2010) [24]. However it's reducing activity is pH dependent, being more at higher pH levels because high pH may increase the efficiency of conversion of hexose sugar to ascorbic acid and is related to the tolerance to pollution (Chouhan *et al.*, 2012) [25]. Chandawat *et al*. (2011) [26] reported pollution load dependent increase in ascorbic acid content of all the plant species and it may be due to the increased rate of production of reactive oxygen species during photo oxidation process of SO_2 where sulphites are generated from SO_2 absorbed. SO_2 exposure would increase the free radical scavenger such as ascorbic acid to protect plants from damage by oxidative stress. Lower ascorbic acid contents in the plant species support the sensitive nature towards the pollutants particularly the automobile exhausts (Randhi and Reddy, 2012) [27]. Ascorbic acid activates many physiological and defence mechanism in the plants (Yannawar and Bhosle, 2013) [28]. Rai *et al*. (2013) [29] reported that ascorbic acid is a stress reducing factor and is present in tolerant plant species generally in higher levels. Plant species maintaining high ascorbic acid content under polluted conditions are considered to be tolerant to air pollution stress (Swami and Chauhan, 2015) [30]. Previous researches reported that boost in the level of ascorbic acid content may be due to the resistance mechanism of plant to cope with stress condition (Garg and Kapoor, 1972 [31]; Joshi *et al.*, 2016) [32].

3.2 Effect on total chlorophyll content

Chlorophyll content of plants signifies its photosynthetic activity as well as the growth and development of biomass (Katiyar and Dubey, 2001) [33].Chlorophyll is known as an important stress metabolites and higher chlorophyll content in plants might favor tolerance to pollutants (Joshi *et al*., 1993) [34]. Chlorophyll content decreases due to production of reactive oxygen species (ROS) in the chloroplast under water stress (ROSs are very small reactive molecules that can cause damage to cell structures during environmental stress). Higher ascorbic acid content of leaves might be an effective strategy to protect thylakoid membranes from oxidative damage under such water stress conditions (Tambussi *et al.*, 2000) [35]. Ninavenave *et al*. (2001) [36] reported that degradation of photosynthetic pigment has been widely used as an indication of air pollution. Dust accumulation on leaf surfaces may also reduce the synthesis of chlorophyll due to shading effect (Singh *et al.*, 2002) [37]. 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) [38]. Singh and Verma (2007) [39] concluded that plants maintaining their chlorophyll even under polluted environment are said to be tolerant ones.

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 (Tripathi and Gautam, 2007) [40]. Chlorophyll content varies with the tolerance as well as sensitivity of the plant species i.e. higher the sensitive nature of the plant species, lower the chlorophyll content (Mir *et al*., 2008) [41]. Joshi and Swami (2009) [42] concluded that the most important photoreceptor in photosynthesis is chlorophyll and its measurement is a significant tool to calculate the effects of air pollutants on plants as it plays a crucial role in plant metabolism; any reduction in chlorophyll content directly affects the plant growth. Agbaire and Esiefarienrhe (2009) [22] reported that certain pollutants increase the chlorophyll content whereas others decrease it. Chandawat *et al*. (2011) [43] revealed that chlorophyll content in all the plants varies with the pollution status of the area i.e. higher the pollution level in the form of vehicular exhausts lower the chlorophyll content. They further reported that chlorophyll content also varies with the tolerance as well as sensitivity of the plant species i.e. higher the sensitive nature of the plant species lower the chlorophyll content. Variation in chlorophyll content among the plant species in the study area may be owing to species tolerant nature, age, genetic makeup and other environmental circumstances in addition to pollution effect (Kumar and Nandini, 2013) [44]. Chlorophyll pigments exist in highly organized state, and under stress they may undergo several photochemical reactions such as oxidation, reduction and reversible bleaching. Hence, any alteration in chlorophyll concentration may change the morphological, physiological and biochemical behaviour of the plant (Bora and Joshi, 2014) [45].

3.3 Effect on leaf extract pH

pH is a biochemical parameter that serves as a sensitivity indicator of air pollution and plants with a pH of around 7 are more pollution-tolerant. The change in leaf extract pH might influence the stomatal sensitivity due to air pollution (Chouhan *et al*., 2012) [25]. It has been reported that in the presence of an acidic pollutant which may be due to the presence of SO_2 and NOx in the ambient air, the leaf pH is lowered and the decline is greater in sensitive than that in tolerant plants (Singh and Verma, 2007 [39]; Rai and Panda, 2014a) [46]. According to Escobedo *et al*. (2008) [9] the photosynthetic efficiency is strongly dependent on the pH of leaf and at low pH the photosynthesis in plant species was reduced in plants. Kumar and Nandini (2013) [44] reported that plants with lower pH are more susceptible while those with pH around 7 are tolerant. pH plays an important role in signifying the condition of plants with respect to the study area (Subramani and Devaanandan, 2015) [47]. Low pH decreases the efficiency of hexose sugar conversion to ascorbic acid and the reducing activity of ascorbic acid is more at higher pH than at lower pH. Thus high pH can provide tolerance to plants against pollutants (Agarwal, 1988)[48]. Leaf pH is reduced in the presence of acidic pollutants and the reducing rate is more in sensitive plants compared to that in tolerant plants (Tiwari and Tiwari, 2006 [49]; Gholami *et al*., 2016) [50].

3.4 Effect on relative water content

The relative water content is associated with protoplasmic permeability in cells which is involved in loss of water and dissolved nutrients resulting in early senescence of leaves (Agrawal and Tiwari, 1997) [51]. Reduction in relative water content of plant species is due to impact of pollutants on transpiration rate in leaves (Swami *et al*., 2004) [52]. Categorization of plants as sensitive or tolerant was determined by the level of biochemical parameters in plants and thus plants show different susceptibility to different pollutants. Sensitive species are an early indicator of pollution and the tolerant species help in reducing the overall pollution load (Nrusimha *et al*., 2005) [53]. If leaf transpiration rate is reduced due to air pollution, plants lose ability to pull water and minerals from roots for biosynthesis. Therefore, maintenance of relative water content by the plant may decide the relative tolerance of plants towards air pollution (Verma, 2003[54]; Rai *et al*., 2013) [55]. Kumar *et al*. (2013) [18] reported that plant species with higher water content under polluted condition may be tolerant to pollutants. Maintenance of the physiological balance in plants is ensured by high water content under stresses such as air pollution (Ogunkunle *et al*., 2015) [56].

4. Acknowledgement

The authors acknowledge the Head, Department of Environmental Sciences, Dr. Y.S Parmar UHF, Nauni, Solan for providing necessary laboratory facilities. The authors are also thankful to the staff of the Department for providing necessary help in some of the analyses.

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