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Plant-Pollutant Interactions with a Special Mention of Dust Accumulation by Plants - A Review

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ABSTRACT

Industrialization has provided humanity with materials and social benefits. It has also brought in its wake up many unwanted substances and social problems. One of these problems is the degradation of the environment. The environment, upon which our life is most dependent, has fallen victim of pollution brought by the man himself through unplanned and unscientific development and mineral exploitation. Air pollution is an inevitable harmful by-product of rapid industrialization and urbanization that is responsible for a variety of deleterious effects on both human and plant communities. It has been a major environmental concern since the beginning of industrialization, resulting in a release of gaseous and particulate pollutants into the atmosphere. A relationship between traffic density and photosynthetic activity, stomatal conductance, total chlorophyll content and leaf senescence has been reported. Exposure of evergreen plants to air pollutants create many changes in physiological and biochemical parameters. Each plant species has a different ability to absorb and adsorb pollutants by their foliar surfaces, which is influenced by several biochemical, physiological and morphological characteristics. Rampant and uncontrolled use of fossil fuels in industries and transport sector has led to an increase in concentrations of the gaseous pollutants. Indian cities are facing serious problems of airborne particulate matter. Atmospheric particulate matter, which is a mixture of diverse elements, is of most concern in context of public health. Particulates may also cause a reduction in yield, change in photosynthesis and transpiration along with foliar injuries. The plant species which accumulate more dust onto their surfaces can act as buffer around industries and along roadsides. The present study deals with the plant-pollutant interactions and how the physical and chemical characteristics of plants vary with air pollution. It also throws light on how dust affects various plant species and what is the role of plants in dust accumulation.

INTRODUCTION

Air pollution refers to the human introduction into the atmosphere of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organism, or damage the environment. Air pollution is a major problem arising mainly from industrialization, unplanned urbanization, alarming increase in vehicle fleet and population growth. With rapid development of human civilization the number of automobiles has increased, which ultimately deteriorates the air quality. World Bank studies in selected cities of developing countries have shown that the ever increasing urban population and rapid growth in the industrial sector and automobile traffic in Asia has caused serious risks associated with air pollution (Anonymous 2009).

The chemical composition of air is changing by introduction of gases, particulates and volatile substances as a result of many human activities. These may even be toxic to the human beings and to the entire flora and fauna at large. 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 refineries, automobiles and industries (Birley & Lock 1999). The impact of such anthropogenic emissions into the atmosphere is responsible for a variety of chronic and acute diseases at the local, regional and global scale (Rawat & Banerjee 1996).

Most of the plant communities are affected by dust deposition and persistent deposition of dust may affect photosynthesis, respiration, transpiration and allow the penetration of phytotoxic gaseous pollutants (Farmer 1993). With an increase in quarrying, open-cast mining and road traffic activities, there has been an increase in dust deposition on vegetation. Persistent deposition of dust on the surface of leaves can adversely affect plants by blocking light and stomata, thereby reducing their photosynthetic rates and contents of chlorophyll, starch, carbohydrates, proteins and amino acid. Visible injury symptoms may occur initially such as chlorosis and necrosis and gradually lead to decreased productivity.

RESPONSES OF PLANTS TO AIR POLLUTION

Plants being an important part of all ecosystems play a crucial role in monitoring and maintaining the ecological balance by actively participating in the cycling of nutrients and gases like carbon dioxide, oxygen, etc. They are most likely to be affected by airborne pollutants and the effects are widely observed on the leaves which are usually the most abundant and most obvious primary receptors of a large number of air pollutants. Plants provide an enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollution level in the air environment (Escobedo et al. 2008). They play an important role in indicating, monitoring and mitigating air pollution.

Adverse impacts of air pollution on biota and ecosystem have been demonstrated worldwide. Much experimental work has been conducted on the analysis of air pollution effects on crops and vegetation at various levels ranging from biochemical to ecosystem levels (Tiwari et al. 2006). The impact of air pollution on the plant community has been studied in terms of plant-environment interactions since the plants are much sensitive in comparison to other organisms (Abbasi et al. 2004).

Various strategies exist for controlling atmospheric pollution, but vegetation provides one of the natural ways of cleaning the atmosphere by absorption of gaseous and particulate matter through leaves (Varshney 1985). Once inside the leaves, the gas diffuses into intercellular spaces and may be absorbed by water films to form acids or react with inner leaf surfaces (Smith 1990). It is also revealed that the interception of dusts by vegetation makes an important contribution to the improvement of air quality in their vicinity (Prajapati 2012). 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 the direct determination of the pollutants in the air over a short period.

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). The use of plants as bio monitors of air pollution has long been established because these are the initial acceptors of air pollutants as they have scavenging property for many air pollutants (Joshi & Swami 2009). Vegetation naturally cleanses the atmosphere by absorbing gases and some particulate matter through leaves and consequently improves environmental quality and human health.

Recent studies have explored the possibility to find out the ability of plants to remove pollutants from the air and act as sink for air contaminants (Sunita & Rao 1997, Dwivedi & Tripathi 2007, Tripathi & Gautam 2007).

Trees act as a sink of air pollutants and thus reduce their concentration in the air (Prajapati & Tripathi 2008). They play an essential role in reducing the airborne particulate pollution in the environment; therefore they should be planted to overcome the pollution problem in the urban areas (Chakre 2006). It has also been found that trees can act as biological filters that can remove a large number of airborne pollutants and hence improve the quality of air in polluted environments (Beckett et al. 1998). Urban trees, especially the low volatile organic compounds (VOC) emitting species can be a viable strategy to help reduce urban ozone levels (Cardelino & Chameides 1990, Tanha, 1996; Nowak et al., 2000) particularly through tree functions that reduce air temperature, remove air pollutants and reduce building energy and consequent power plant emissions. The foliage of plants, filters several numerous solid particles due to roughness and large contact area and thus can reduce the damaging effect of particulate pollution. (Meusel et al. 1999). Leaves and exposed parts of a plant act as persistent absorbers in a polluted environment (Samal & Santra 2002).

RELATIONSHIP OF TREE CHARACTERISTICS WITH AIR POLLUTION

Physical Characteristics

The diffusion pathway of absorbed pollutants is through the stomata and resistance to flow is determined by the frequency and distribution of stomata available for entry and by dimensions of their apertures (Meidner & Mansfield 1968). Circumstantial evidence indicating that a decreased stomatal frequency may accompany an increase in pollution levels has been reported by Sharma & Butler (1973, 1975) and Sharma (1975). The cuticle is an effective barrier to the penetration of gases into the leaf interior (Unsworth et al. 1976). Although the potential for limited pollutant penetration through the cuticle is acknowledged, there is no evidence to suggest that this contributes significantly to the internal pollutant concentration. Many factors are known to influence the response of vegetation to gaseous air pollutants (Heck 1968). Jacobson et al. (1966) indicate that higher transpiration rates at leaf margin may account for marginal necrosis following exposure to fluoride, while Brennan & Leone (1968) investigated the extent of foliar necrosis caused by sulphur dioxide or ozone.

Air pollutants damage plants, impair plant growth, and limit primary productivity, according to the sensitiveness of plants to pollutants (Ulrich 1984). The trees in urban environments, improve air quality by enhancing the uptake of gases and particulate matter, especially near roadways (Smith 1971). Atmospheric pollutants like SO_2 adversely affect various morphological and physiological characteristics of plants. High soil moisture and high relative humidity aggravate SO_2 injury in plants. Pollutants can also cause leaf injury, stomatal damage, premature senescence, decreased photosynthetic activity, disturbed membrane permeability and reduced growth and yield in sensitive plant species (Tiwari et al. 2006). Chlorosis of the leaf tip is the first visible injury which gets extended inwards from veins and along margins. Damages caused by air pollutants to plants include chlorosis, necrosis, and epinasty (Katiyar & Dubey 2000).

The effectiveness of a greenbelt in intercepting and retaining atmospheric pollutant depends upon several factors, viz., shape, size, moisture level, surface texture, nature (soluble or insoluble) of both the particulate matter and gas as well as intercepting plant parts (Ingold 1971). The properties of leaves such as wettability, exposure, leaf orientation, age and roughness, strongly influence the dust interception and retention (Beckett et al. 2000). Most plants experience physiological changes before exhibiting visible damage to leaves when exposed to air pollutants (Tripathi & Gautam 2007). Rai et al. (2011) stressed that air pollutants pose risks on yield of crops depending upon the emission pattern, atmospheric transport and leaf uptake and on the plant's biochemical defence capacity. Several vital physiological processes such as photosynthetic CO_2 fixation and energy metabolism are also affected negatively by air pollutants. The adverse effect on plants depends not only upon the concentration of air pollutants, but also on the duration and combination of air pollutants. The filtering effects of evergreen trees have been reported to be better than that of deciduous trees (Dochinger 1973). Single row of trees planted with or without shrubs can reduce particulate matter by 25 percent (Anonymous 1981). Trees reduce air pollution by intercepting airborne particles and retaining them on the leaf surface, referred to as dry deposition. Some particles can be absorbed by the leaf surface itself, although most remain on the plant surface (Joshi & Chauhan 2008).

The effectiveness of internal leaf tissue to extract pollutants is determined by the extent of cell surface area and degree of hydration. The state of hydration is vital since some studies indicate that the pollutant first reacts with water and then in hydrated form interacts with the cell constituents (Hocking & Hocking 1977). According to Taylor (1978), more is the surface area for removal, more rapid is the extraction of the pollutant from the intercellular space on to cell surfaces. Even though pollutant molecules and their toxic derivatives react with water at the cell surface and then subsequently cross the plasmolemma into the cell, the potential toxicity of the pollutant may never be realized if the cell possesses mechanisms which are capable of eliminating the harmful molecules that cause strain. In theory, three mechanisms are envisaged which are: The capacity to (1) tolerate, (2) assimilate, (3) buffer the potentially toxic derivatives.

The capacity to tolerate potentially toxic pollutant derivatives is a mechanism whereby cellular metabolism continues unaffected despite the presence of harmful pollutant molecules. The strain avoidance is estimated with the help of a biochemical threshold level (Malhotra & Hocking 1976).

Chemical Characteristics

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 (Singh & Verma 2007). The sensitive species help to indicate air pollution and tolerant ones help in abatement of air pollution. The tolerant species of plants function as pollution sink and therefore, a number of environmental benefits can be obtained by planting tolerant species in polluted areas. For this purpose, evaluation of plants with respect to their tolerance level to air pollution may be essential (Lakshmi et al. 2009). There are many factors controlling tolerance in plants. From the scientific studies, information is obtained about the plant pollutant interaction and role of absorption of pollutants. Industrial areas, residential areas and roadsides are the targeted places for green belts. Primary pollutants are taken up based on the fate of transport of the pollutant within the plant body and form in which it ends. When the pollutants are taken up at a higher rate, it causes injury to the plants. Pollutants enter plants through the stomata apertures. The gaseous pollutant passes through the mesophyll intercellular spaces and gets absorbed on the wet cell-walls and further diffuses into the cell sap. The capacity to assimilate the pollutant derivatives is based upon the plant's ability to metabolize the pollutant to a less harmful form and to remove them through deposition or translocation to sinks within the leaf or other plant organs (Taylor 1978). The capacity to buffer toxic derivatives as a mechanism of strain avoidance is based upon two assumptions: (i) the derivatives of pollutants alter the cell's ability to buffer against changes in H^+ and OH^- (ii) such changes cause strain.

Particulates affect various biochemical changes such as decreased chlorophyll content and increased ascorbic acid (Mandal & Mukherji 2000, Garty et al. 2001, Masitha & Pise 2001, Gavali et al. 2002) have been reported. Vegetation naturally cleanses the atmosphere by absorbing gases and some particulate matter through leaves and consequently improves environmental quality and human health. Trees remove pollution by intercepting airborne particles. Once inside the leaves the gas diffuses into intercellular spaces and may be absorbed by water films to form acids or react with inner leaf surfaces (Smith 1990). Agricultural activities and vehicular traffic are reported to accumulate more dust on trees grown near to the source and found to exceed the environmental guideline values (Leys et al. 1998 and Mannis et al. 2001). Presence of SO_2 degrades the chlorophyll molecule through oxidation (Keller & Schwager 1977, Chaudhary & Rao 1977, Davis & Wilhour 1976, Bell & Mudd 1976). NO_x absorption causes a reaction on cell walls to form HNO_2 and HNO_3.

Leaf extract pH: The importance of pH in modifying the toxicity of SO2 has been shown in many studies. It was reported that plants with lower pH are more susceptible, while those with pH around 7 are more tolerant (Singh & Verma 2007). Ogunkunle et al. (2015) observed that changes in pH were pronounced and significant in *Acacia nilotica*, *Prosopis african*a and *Terminalia catappa*. *Vitellaria paradoxa* also showed a significant change in the pH of the leaf extracts between the control and exposed locations, but no significant difference was observed across the exposed locations. High pH may increase the efficiency of conversion from hexose sugar to ascorbic acid, while low leaf extract pH shows a good correlation with sensitivity to air pollution (Escobedo et al. 2008). When cellular pH is lowered, metabolism is inhibited leading to growth suppression.

Total chlorophyll content: Depletion in chlorophyll immediately causes a decrease in productivity of plant and subsequently plant exhibits poor vigour. Therefore, plants maintaining their chlorophyll, even under polluted environment are said to be tolerant ones (Singh & Verma 2007). It was also found that the chlorophyll content differed significantly across the locations for all of the tree species. The highest chlorophyll contents for *A. nilotica*, *P. africana* and *V. paradoxa* were recorded at the staff residence (moderate traffic density), while *T. paradoxa* exhibited the highest chlorophyll content in the academic area (maximum traffic density). The control site had the least chlorophyll content for *A. nilotica, P. Africana* and *T. catappa*. The high chlorophyll content recorded at the staff residence showed that *A nilotica, P. africana* and *V. paradoxa* exhibited tolerance to pollution in the area.

A study conducted by Giri et al. (2013) indicated a decline in the chlorophyll content in trees growing in the industrial areas and it was suggested that the reduction in chlorophyll content was due to degradation of chlorophyll into phaeophytin by the loss of magnesium ions. Reduction in the concentration of chlorophyll content in leaves of polluted area was observed in the plant species studied by Amulya et al. (2015). Similar changes in concentration of pigments were also observed in the six tree species studies which were exposed to air pollution due to vehicle emission (Joshi & Swami 2009). It was also observed that leaves from polluted area had significantly lower chlorophyll content than control (Tripati & Prajapathi 2008, Stevovic et al. 2010).

The effect of dust on the pigmentation and growth of *Vitis vinifera* L. was studied in 2012 by Leghari et al. (2014) and a significant reduction in plant length, cover, number of leaves and total chlorophyll content was observed. It was observed that there was a negative correlation between the amount of dust accumulation and the plant growth parameters.

Ascorbic acid: Ascorbic acid plays a significant role in light reaction of photosynthesis (Singh & Verma 2007), activates defence mechanism (Arora et al. 2002) and under stress condition, it can replace water from the light reaction II (Singh & Verma 2007). Ascorbic acid, a natural antioxidant in plants has been shown to play an important role in pollution tolerance (Joshi & Swami 2007). It also plays a role in cell wall synthesis, defence and cell division. It is also a strong reducer and plays important roles in photosynthetic carbon fixation, with the reducing power directly proportional to its concentration.

Bermadinger et al. (1990) and Kousar et al. (2014) also noticed that the ascorbic acid contents of tree species increased because of air pollution. Ascorbic acid is a natural detoxicant that prevents the damaging effect of air pollutants in plant tissues (Singh et al. 1991). Large amounts of ascorbic acid favour defence properties and pollution tolerance in plants (Lee et al. 1984, Cheng et al. 2007) and indicate high pollution levels.

Relative water content (RWC): High water content in plants ensures the maintenance of the physiological balance under stresses such as air pollution, and the RWC is usually associated with the protoplasmic permeability of cells, which is involved in the loss of water and dissolved nutrients in plants, resulting in senescence of leaves (Agarwal & Tiwari 1997 and Tsega & Prasad 2014). Ogunkunle et al. (2015) observed that RWC varied significantly across the locations in all the studied tree species, the lowest RWCs were recorded in all the tree species growing in the staff residence area (moderate traffic density), while the highest RWCs were recorded in the tree species growing in the student residence area (minimal traffic density). Studies conducted by various researchers have shown an increase in the relative water content with the rise in pollution. Relative water content has been found to vary with air pollution. In various studies, it has been observed that RWC was higher at the polluted sites as compared to the control site (Patel & Kousar 2011, Amulya et al. 2015).

Benzene: Another pollutant 'Benzene' is recognized as human leukaemogen and may cause injury to human bone marrow and damage to the immune system. In India, especially in Delhi, since 2008 onwards, the concentration of benzene has shown a remarkable increase in its diurnal as well as nocturnal trend. In order to minimize the concentration of benzene in air, common plants like *Dracaena deremensis* and *Chamaedoreas seifrizii* have been suggested by estimating Air Pollution Tolerance Index (APTI) values. *Dracaena deremensis* has been found to be tolerant and also good absorber of benzene in the air by a NASA study, while *Chamaedorea seifrizii* was found to be sensitive and can serve as bioindicator which might further help in mitigating the benzene pollution (Saxena & Ghosh 2015).

Thus, these biochemical and physiological parameters are readily affected by pollutants and their study can reveal the quality of air.

DUST ACCUMULATION BY LEAVES

Interaction between plant morphology and dust accumulation: Atmospheric particulate matter is a mixture of diverse elements. Atmospheric particulate matter (PM) with aerodynamic diameter < 10 µm (PM_{10}) or < 2.5 µm ($PM_{2.5}$) is of most concern in context of public health because of the presence of PAHs (Polycyclic Aromatic Hydrocarbons) (NEPC 1998, 2003). Many epidemiologic studies have highlighted the health implications of fine particles with aerodynamic diameter smaller than 10 µm. (Katsouyanni et al. 2001, Kunzli et al. 2000, Pope et al. 2002, Peng et al. 2005 and Prajapati et al. 2006). Removal of pollutants by plants from the air is done by three means, namely absorption by the leaves, deposition of particulates and aerosols over the leaf surface, and fallout of particulates on the leeward side of vegetation which ultimately is decided by air movement (Rawat & Banerjee 1996). Mineral dusts in general are less soluble and less reactive as compared to the anthropogenic acid-forming sulphate and nitrate particles (Flower et al. 1989, Grantz et al. 2003). Dusts with pH values ≥ 9, may cause direct injury to the leaf tissues on which they get deposited (Vardak et al. 1995) or indirectly through soil pH alteration (Hope et al. 1991, Auerbach et al. 1997). The direct physical effects of mineral dusts on vegetation became apparent only at relatively high surface loads of more than 7 g m^{-2} (Farmer 1993) as compared with the chemical effects of reactive materials such as cement dust which may become evident at 2 g m^{-2} (Grantz et al. 2003).

Limestone and cement dusts, with pH values of 9 or higher may cause direct injury to leaf tissues (Vardak et al. 1995) or indirect injury through alteration of soil pH (Hope et al. 1991, Auerbach et al. 1997). Air particulates affect the overall growth and development of plants according to their physical and chemical nature (Gupta & Ghouse 1987). Air particulates also alter the morphology and anatomy of the leaves (Farooq et al. 2000, Pal et al. 2000, Shrivastava & Joshi 2002, Garg et al. 2000). Surface dust deposit may alter the optical properties of leaves, particularly the surface reflectance in the visible and short wave infra-red radiation range (Eller 1997, Hope et al. 1991, Keller & Lamprecht 1995).

Hicks (1986) reported in his work that although the rate of dry deposition of atmospheric particles to a plant and soil is much slower as compared to occult (wet) deposition, nevertheless it acts nearly continuously and affects all the exposed parts of plant. The important physical properties of dusts which determine the potential transport distance from a source are gravity specific and dependant on the particle size. Gravitational sedimentation is the main depositional process, for particles >1 µm diameter, while for particles < 0.001 µm diameter, i.e. RSPM (Respiratory Suspended Particulate Matter), inertial properties become increasingly important (Chamberlin 1986, Flower et al. 1989, Wesely & Hicks 2000, Raupach et al. 2001). Properties of both particles and the vegetation are important in deciding their interactions, and consequently the effectiveness of particle removal from atmosphere (Prajapati 2012). Dust capturing capacity of plants depends on their surface geometry, phyllotaxy and characteristics such as hair, cuticle, height and canopy of tree.

Walker & Everett (1987) reported that there is a decrease in leaf surface dust load with increasing distance from highways. Keller & Lamprecht (1995) reported that dust levels near the Dalton Highway in Alaska were relatively invariable over much of the summer growing season and that over 85% of the dust falling on vegetation surfaces may be removed. Chattopadhyay (1996) reported that leaves respond to pollution and undergo quantitative changes in varying degree in a number of leaf surface micromorphological characters. The capacity of tree species to intercept dust depends on its surface geometry, phyllotaxy, leaf external characteristics (such as hairs, cuticles etc.) and height (Nowak 1994 and Singh 2000).

Leaves tend to have differences in several aspects of their surfaces. Some types of leaves have greater surface rigidity or roughness than others, which may affect their stickiness or particle solubility. Therefore, certain plant leaves may be more useful for efficient dust capturing than other plants (Anonymous 2006). The leaves with complex shapes and large circumference area collect particles more efficiently than simple leaves with smaller area (Ingold 1971). Plants with leaves having a large surface area function as an efficient pollutant trapping device.

Role of plants in dust accumulation: Investigations related to quantification of the dust capturing capacity of urban canopies have received attention in the recent past decades (Ram et al. 2015). The estimations of removal of atmospheric particulate matter by plants have been done by several researchers. For example, trees in Beijing, China captured 1,261.4 tons of pollutants that resulted in a reduction of 772 tons of PM_{10} per annum from the air (Yang et al. 2005). Nowak et al. (2006) demonstrated the variation in pollution removal by urban trees in several U.S. cities and estimated that the total annual air pollution removal by urban trees is approximately 7,11,000 metric tons ($3.8 billion value). Removal of approximately 4% and 3% of PM_{10} annually by urban plant canopies in West Midlands and Glasgow, United Kingdom, respectively, was reported by McDonald et al. (2007). Suspended particulate matter usually clogs stomata apertures and prevents the exchange of gases by leaves. The film of dust causes a hazardous situation for plants as it results in reduction of effective pollination (Anonymous 1983).

Maheshwari (1963), Chee & Ridwan (1984) and Shetye & Chaphekar (1980) surveyed the dust fall on common roadside trees in Mumbai (India) and reported that the leaves of Mango (*Mangifera indica*), Ashoka (*Polyalthia longifolia*), Pongamia (*Derris indica*) and Umbrella (*Thespepsia populnea*) trees captured higher amounts of dust as compared to other neighbouring plants. Filtering capacity of green belts increases with more leaf area, and is reported higher for trees than bushes or grassland (Givoni 1991).

Wang et al. (2011) investigated the leaf dust capturing capacities of 14 common urban greening plants and their relationships with surface micro-morphology. Among the selected plant species, leaf dust capturing capacities ranged from 0.23 g m^{-2} (*Trifolium repens*) to 4.51 g m^{-2} (*Pittosporum tobira*). The study concluded that plants with higher dust capturing capacities and with leaf micro-morphological properties such as epidermal cell, wax and sunken stomata can be recommended for introducing as urban greening plant species.

Many trees like neem (*Azadirachta indica*), silk cotton (*Bombax ceiba*), Indian laburnum (*Cassia fistula*), gulmohar (*Delonix regia*), pipal (*Ficus religiosa*), jacaranda (*Jacaranda mimosifolia*), Indian lilac (*Lagerstroemia indica*), temple tree (*Plumeria rubra*), Java plum (*Syzygium cumini*) and several other roadside and street trees have been found to be more suitable in urban environment.

The deposition of gaseous pollutants and particulate matter and their interception are greater in woodlands than in shorter vegetation (Fowler et al. 1989, Bunzl et al. 1989). The presence of trees in the urban environment can thus improve air quality by enhancing the uptake of gases and particles (McPherson et al. 1994, Beckett et al. 1998, 2000, Freer-Smith et al. 1989) near roadways (Smith 1971) and in agricultural situations (Raupach et al. 2001). Leaf petioles are more efficient particulate impactors than either twigs (stems) or leaf lamina (Ingold 1971). Green belts reduce noise pollution (Pal et al. 2000, Fang & Ling 2005, Martinez Sala et al. 2006). The trees and shrubs have been identified as dust filters to check the rising urban dust pollution level in the area (Rai et al. 2010).

Prajapati & Tripathi (2008) while studying the dust interception efficiency and impact of dust deposition on biochemical properties of leaves of some selected tree species such as *Ficus religiosa*, *Ficus benghalensis*, *Mangifera indica*, *Dalbergia sissoo*, *Psidium guajava* and *Dendrocalamus strictus*, found maximum dust interception on the leaves of *Dalbergia sissoo* and least on *Dendrocalamus strictus*. It was found that all species have maximum dust deposition in the winter season followed by summer and rainy seasons. An investigation of the seasonal variation in dust accumulation on leaves and leaf pigment content of six plant species of mixed habitats was carried out on the sides of the National Highway (NH 6) at Sambalpur, Orissa, India. The plants selected for study were *Pongamia pinnata*, *Tabernaemontana divaricata*, *Ipomea carnea*, *Ficus religiosa*, *Ficus benghalensis* and *Quisqualis indica*. The observed rend of dust accumulation was in the order *T. divaricata* > *I. carneaipomea* > *P. pinnata* > *F. religiosa* > *F. benghalensis* > *Q. indica*. One-way analysis of variance showed significant difference in dust accumulation among plant species ($F1 = 4.674$, $P < 0.01$ and between $F2 = 9.240$, $P < 0.01$). It was seen that dust load increases with the increasing number of vehicles on highway (major emission source). The result shows significant negative correlations between dust load and pigment in summer and rainy season (Prusty et al. 2003).

Raina et al. (2008) reported that dust impairs visibility and the particulate dust falling on leaves may cause foliar injuries, reduction in yield, change in photosynthesis and transpiration etc. Qin Li et al. (2010) determined the plant resistance to dust accumulation in seven common green plants growing on the three streets of Nanning City viz., You'ailijiao, Minzudadao and Baishadadao. The dust accumulation effects on different green plants were worked out through analysing different classification indices, viz., plant height, leaf area index, dust quantity per unit area, plant resistance and leaf characteristics.

Rai et al. (2014) agreed that plants can be used in the abatement of dust pollution by acting as natural fibres. The results also displayed significant negative and positive correlation between the dust content and biochemical parameters (mainly pH, total chlorophyll content and relative water content).

Plants are adversely affected by pollution, but study of the biochemical and physiological parameters of plants can serve as an early warning system of the deteriorating quality of air. The plants which are most efficient in dust accumulation can serve as a buffer zone around industries and along roadsides.

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