Impact of air quality on physiological attributes of certain plants.

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Abstract: The ambient air quality monitoring was carried along the NH - 58 through Haridwar and other 3 traffic intersection of the city. The maximum concentration of SO_2 (17.64µg/m^3), NO_x (23.46 µg/m^3) and SPM (398 µg/m^3) was found at site IV during the study period December 2009 to March 2010. The study also examined the dust interception efficiency and air pollution tolerance index (APTI) of 8 plant species by using four biochemical parameters; relative water content, leaf pH, ascorbic content and total chlorophyll. The results showed that combining variety of these parameters give more reliable results than those of individual parameter. Maximum dust interception was done by *Psidium gujava* and species *Ficus religiosa* has highest air pollution tolerance index. The study indicated that ambient air pollution has negative impact on physiological characteristics of plants.

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1. Introduction

In urban areas vehicular pollution is predominant and significantly contributes to air quality problems. The air quality is generally described as a combination of the physical and chemical characteristics that make air a healthful resource for man, animal and plants. The Air Pollution Index (API) is a number used to categorize the quality of the air at a given location (Tripathi and Gautam, 2006). Air pollutants can directly affect plants *via* leaves or indirectly *via* soil acidification (Steubing *et al*, 1989). Pollutants when absorbed by the leaves cause a reduction in the concentration of photosynthetic pigment *viz.* chlorophyll which directly affects the plant productivity.

Plants are the only living organisms, which have to suffer a lot from automobile exhaust pollution because they remain static at their habitat. But road side plants can easily avoid the effects of air pollutions by altering their physiological pathways pertaining the photosynthesis and respiration. Stomatal clogging and closure help these plants in preventing the entry of poisonous gases (Mandal 2006). Responses of plants towards air pollutants were assessed by air pollution tolerance index (APTI), is an index denotes capability of a plant to combat against air pollution (Chauhan, 2010). The use of plants as monitor of air pollution has long been established, as plants are the first interceptors of air pollutants. Presence of trees in the urban environment can improve air quality through enhancing the uptake of gases and particles.

Present study has been undertaken to study the effect of ambient particulates and gaseous pollutants on physiological attributes and air pollution tolerance index (APTI) of certain plant species.

2. Materials and Methods

2.1 Study sites

Haridwar, located in the state of Uttarakhand is one of the important holy cities of India and is extended from 29°58′ latitude and 78°13′ longitude with a subtropical climate. It receives millions of tourists every month, sometimes just in one day, which increases the number of automobiles of various categories up to 120% per day. The present study was conducted at four different sites namely Singh Dwar (Site I), Chandracharya Chowk (Site II), Chandi Bridge (Site III) and CISF Barrier, SIDCUL (Site IV).

2.2 Leaf sampling and biochemical analysis

On each sampling day 3 leaf samples were collected and biochemical parameters were estimated in five replicates. The tree species of *Cassia fistula, Bougainvillea glabra, Psidium gujava, Ficus benghalensis, Azadirachta indica, Ficus religiosa, Saraca indica* and *Eucalyptus* sps. selected in the present study. The amount of dust was calculated by taking the initial and final weight of beaker in which the leaf samples were washed. The estimation of chlorophyll content was assessed according to the method proposed by Arnon (1949), ascorbic acid by Agarwal (1985), pH was determined by digital pH meter and relative water content through the method given by Weatherly (1965). APTI was calculated by using the formula given by Singh and Rao (1983). API of 4 different sites were calculated by Rao and Rao (1989).

3. Results and Discussion

The concentration of primary air pollutants has been given in Table 1, it could be noticed that the higher concentration of SPM was recorded at Site IV *i.e.* 398µg/m^3 and least concentration at Site III *i.e.*370µg/m^3. The range of SPM concentration at Site I and II was found to be 376µg/m^3 and 374µg/m^3 respectively. The higher level of SO_2 was recorded at Site IV *i.e.* 17.64µg/m^3 and least was recorded at Site III *i.e.* 9.89µg/m^3. The average concentration of SO_2 at Site I and Site II was found to be 12.96 µg/m^3 and 11.77µg/m^3. Site IV posses higher concentration of NOx *i.e.* 23.46µg/m^3 and Site III with least concentration of 12.98µg/m^3. The average concentration of NOx at Site I and Site II was found to be 19.41µg/m^3 and 18.86µg/m^3. The Site IV was considered to be more polluted site than other 3 sites, since it posses higher concentration of primary air pollutants (SPM, SO_2 and NO_X), because of both vehicular and industrial set up. The ambient air quality is assessed by comparing the level of pollutants in an area with its corresponding air quality standards. The values of Air Pollution Index (API) were varies from 101.66 to 117.56; with maximum at site IV.

TABLE- 1: Ambient Air Quality and Air Pollution Index for different sites.

Sampling Sites	Pollutants (µg/m^3)			Air Pollution Index
	SPM	SO_2	NOx	
Site- I	376	12.96	19.41	107.46
Site- II	374	11.77	18.86	105.06
Site-III	370	9.89	12.98	101.66
Site- IV	398	17.64	23.46	117.56

SPM = Suspended particulate matter

Table-2: Dust load, Biochemical Parameters and Tolerance index of few selected plants.

(All values are mean ± S.E. of 5 observations each).

Biochemical Parameters	PLANT SPECIES							
	Cassia fistula	*Bougainvillea glabra*	*Psidium gujava*	*Ficus bengalensis*	*Azadirachta indica*	*Ficus religiosa*	*Saraca indica*	*Eucalyptus* sps.
Dust Load (gm/m^2)	0.69	0.71	0.79	0.72	0.65	0.69	0.54	0.56
Relative Water Content (%)	69.3±0.75	68.03±1.15	70.37±1.36	69.9±1.36	67.47±0.85	71.81±1.03	63.06±1.01	62.16±0.08
pH	6.1±0.23	6.3±0.18	6.4±0.16	6.5±0.13	6.2±0.16	6.7±0.18	6.6±0.17	6.4±0.16
Ascorbic Acid (mg/g)	5.92±0.04	6.6±0.05	6.88±0.04	6.32±0.03	6.72±0.08	7.28±0.04	7.12±0.03	6.56±0.04
Total Chlorophyll (mg/g)	5.49±0.57	4.05±0.01	6.29±0.78	6.78±0.53	7.60±1.63	12.2±0.52	6.89±0.16	4.58±0.26
Air Pollution Tolerance Index	13.79	13.83	15.76	15.38	16.02	20.94	15.91	13.41

Dust from highways and roads can greatly affect roadside vegetation communities. They have observed changes in pH, water availability, species composition and diversity (Smith, 1971). Removal of pollutants by plants from air is by 3 means namely absorption by leaves, deposition of particulates and aerosols over leaf surface (Tiwari, 1994). In the present study 8 plant species with different leaf characteristics from different sites were studied with heavy particulate pollutants in the atmosphere to evaluate their respective pollution mitigating ability. Dust interception capacity of plants depends on their surface geometry, phyllotaxy and leaf external characteristics such as hairs, cuticle, length of petioles, height and canopy of trees etc; weather conditions with direction and speed of wind (Prajapati, 2008). Highest dust accumulation in *Psidium gujava*, 0.79 gm/m^2 may be due to waxy coating, slightly folded margins, rough surface and small petioles that reduce movement of leaves in wind, while in case of *Ficus bengalensis* and *Bougainvillea glabra* rate *of* dust accumulation was found to be 0.72 and 0.71 gm/m^2 may be due to shiny, waxy coating and rough surface with short petiole, respectively. Dust accumulation in *Ficus religiosa* and *Cassia fistula*, 0.69 gm/m^2 may be due to long petiole that helps the wind to flutter during the wind.

Lower dust accumulation in *Azadirachta indica*, 0.65 gm/m^2 may be due to thin lamina and plane surface, similarly lower dust accumulation in *Saraca indica* and *Eucalyptus* sps. *i.e.* 0.54 and 0.56 gm/m^2 may be due to the long petiole and vertical position of their leaves which prevent dust retention.

The trend of dust deposition among the species was *Psidium gujava* > *Ficus bengalensis* > *Bougainvillea glabra* > *Ficus religiosa* = *Cassia fistula* > *Eucalyptus* sps. > *Saraca indica*, due to different dust interception capacity of leaves. The influence of leaf characteristics on dust accumulation have also been studied by Vora and Bhatnagar, 1986.

Leaf Relative Water Content (RWC) is the appropriate measure of plant water status in terms of physiological consequence of cellular water deficit or RWC of a leaf is the water content present in it which help to maintain its physiological balance under stress condition caused by pollution especially when the prevailing transpiration rate are high (Tiwari and Rai, 2001). It also serves as an indicator of drought resistance plant. RWC of the selected plant species was found to be *Ficus religiosa* (71.81 ± 0.09), *Psidium gujava* (70.37 ± 1.03), *Ficus bengalensis* (69.9 ±1.36), *Cassia fistula* (69.3 ± 0.75), *Bougainvillea glabra* (68.03 ± 1.15), *Azadirachta indica* (67.47 ± 0.85), *Saraca indica* (63.06 ± 1.01) and *Eucalyptus* sps. (62.16 ± 0.08) in a decreasing order. Reduction in relative water content of plant species is due to impact of pollutants on transpiration rate in leaves (Swami *et al.* 2004). According to Lakshmi *et al.* 2009, RWC ranged between 58% to 73% in intermediately tolerant species and 51.3% to 84% in sensitive plant species and thus, in the present study all species are intermediately tolerant species.

pH is a biochemical parameter that acts as an indicator for sensitivity to air pollution (Scholz and Rick, 1977). In the present study leaf pH values were found higher than 6.0 in all species *i.e. Cassia fistula* (6.1 ± 0.23), *Azadirachta indica* (6.2 ± 0.16), *Bougainvillea glabra* (6.3 ± 0.18), *Psidium gujava* (6.4 ± 0.16), *Eucalyptus* sps. (6.4 ± 0.26), *Ficus bengalensis* (6.5 ± 0.13), *Saraca indica* (6.6 ± 0.17) and *Ficus religiosa* (6.7 ± 0.18), is in increasing order. High pH may increase the efficiency of conversion from hexose sugar to ascorbic acid (Escobedo *et al.* 2008) while low leaf pH extract showed good correlation with sensitivity to air pollution and also reduce photosynthesis process in plants. The photosynthetic efficiency has been reported to be strongly dependent on leaf pH (Yan-ju liu and Hui ding, 2008). The photosynthesis was reduced in plants with low leaf pH (Turk and Wirth, 1975). The pH ranged between 4.4 and 8.8 lies in both intermediately tolerant and sensitive plant species (Lakshmi *et al.* 2009) and thus all plant species are both intermediately tolerant and sensitive to air pollutants.

The variation in leaf pigment (Chlorophyll and Ascorbic acid) content in plants is because of various environmental factors such as air, water and soil (Katiyar, 2000). Chlorophyll is the Principal photoreceptor in photosynthesis, its 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). As per the results, higher concentration of Chlorophyll was recorded in *Ficus religiosa* (12.2 ± 0.52) and least was recorded in *Bougainvillea glabra* (4.05 ±0.01). In plant species like *Azadirachta indica, Saraca indica, Ficus bengalensis, Psidium gujava, Cassia fistula* and *Eucalyptus* sps. Chlorophyll concentration was found to be 7.60 ± 1.63, 6.89 ± 0.78, 6.78 ± 0.53, 6.29 ± 0.78, 5.49 ± 0.57 and 4.58 ± 0.26 respectively, is in decreasing order. Decrease in Chlorophyll content of leaves may be due to the alkaline condition created by dissolution of chemicals present in the dust particulates *i.e.* metals and polycyclic hydrocarbons in cell sap which block the Stomatal spores for diffusion of air and thus put stress on plant metabolism resulting in Chlorophyll degradation (Anthony, 2001). Another reason for degradation of Chlorophyll pigment attributed to action of SO_2 and NOx on the metabolism of Chlorophyll, Both of these gases are the constituents of vehicular emission (Leu horth and Dadd, 1981). The reduction in the concentration of chlorophyll might have also been caused due to the increase in chlorophyllase enzyme activities which in turn effects the Chlorophyll concentration in plants (Mandal and Mukherjee, 2000). The Chlorophyll content ranged between 4 mg to 16 mg in intermediately tolerant sensitive species (Lakshmi *et al.* 2009). Thus, all plant species undertaken for study were intermediately tolerant plants against pollution load and dust particulates.

Ascorbic acid, a natural antioxidant has been shown to play an important role in pollution tolerance, it activates many physiological and defence mechanism in plants (Chen *et al.*1990).

It is found in green leaves and has been suggested to have a protective role in chloroplasts. It is directly or indirectly concerned with photosynthetic reactions. Ascorbic acid content of all the species may be due to the rate of production of ROS (Reacting oxygen species) such as SO_2, HSO_3, OH, O_2 etc. during photo oxidation of SO_3 and the rate of production of ROS (Reacting oxygen species) such as SO_2, HSO_3, OH, O_2 etc. during photo oxidation of SO_3 and SO_4 (Agarwal, 2003). The highest content of ascorbic acid was recorded in *Ficus religiosa* (7.28 ± 0.04) and least content was recorded in *Cassia fistula* (5.92±0.04) whereas in other plant species like *Bougainvillea glabra, Ficus bengalensis, Eucalyptus* sps., *Azadirachta indica, Psidium gujava, Saraca indica* ascorbic acid content was found to be 6.6 ± 0.05, 6.32 ± 0.03, 6.56 ± 0.04, 6.72 ±0.08 and 7.12 ± 0.03 respectively, in increasing order and this increase level of ascorbic acid may be due to the defense mechanism of plant to cope with stress condition since it retards leaf senescence (Garg and Kapoor, 1972). The ascorbic content ranged between 7.52 to 11.05 mg in intermediately tolerant species and 1.61 to 8.23 mg among the sensitive plant species (Lakshmi *et al.* 2009). In the present study the ascorbic acid content of all the plant species varies between 1.61 to 8.23 and were categorized as sensitive plant species, thus act as biological indicators of air pollution.

Air pollution tolerance index plays a significant role to determine resistivity and susceptibility of plant species against pollution level. To evaluate the tolerance level of plant species to air pollution Singh and Rao (1983) used 4 leaf parameters (*i.e.* relative water content, pH, chlorophyll content and ascorbic acid) to derive an empirical number indicating the air pollution tolerance index. Thus, combining a variety of parameters give a more reliable result than when based on a single biochemical parameter.

Air pollution tolerance level of studied plant species was found to be *Eucalyptus* sps.(13.41), *Cassia fistula* 13.79, *Bougainvillea glabra* (13.83), *Ficus bengalensis* (15.38), *Psidium gujava* (15.76), *Saraca indica* (15.91), *Azadirachta indica* (16.02) and *Ficus religiosa* (20.94); in increasing order. Plants which have higher APTI value are more capable to combat against air pollution and can be used as sinker to mitigate pollution, while plants having low index value show less tolerance and can be used to indicate levels of air pollution. High value of APTI was recorded in *Ficus religiosa*.

APTI value less than 10 are termed as sensitive species which can be used for biomonitoring of air pollutants (Agarwal *et al.* 1991). All the above mentioned species were intermediately tolerant species. Level of air pollution tolerance varies from species to species depending on the capacity of plants to the effect of pollutants without showing any external damage.

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