Photosynthetic Pigment Changes In Some Selected Trees induced By Automobile Exhaust in Dehradun, Uttarakhand

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Abstract: Study was carried out to assess the impact of automobile exhaust on some selected tree species grown at the famous Clock Tower in Dehradun city, world famous tourist spot in Northern India. The plant species selected for the study were *Ficus religiosa*, *Mangifera indica*, *Polyalthia longifolia*, *Delonix regia*. Reduction in chlorophyll '*a*', chlorophyll '*b*', total chlorophyll content, ascorbic acid, carotenoid, pH, relative water content and APTI was recorded in the leaf samples of all selected trees collected from polluted site when compared with samples from control area. The data obtained were further analyzed by using two-way ANOVA and also obtained significant changes in all these parameters samples collected from polluted site trees, exposed to automobile exhaust in comparison to control site. There was maximum (38.13 %) reduction of chlorophyll '*a*' content in the leaves of *Ficus religiosa* and minimum (20.13%) reduction was in the *Mangifera indica*, while maximum (30.94%) carotenoid was depleted in *Polyalthia longifolia* and minimum (19.64%) depleted in *Mangifera indica* at polluted site as compared to control site. The maximum (39.87%) reduction of ascorbic acid was observed in the leaves of *Delonix regia* and minimum (21.38%) reduction was observed in the leaves of *Polyalthia longifolia*. [New York Science Journal. 2010;3(2):45-51]. (ISSN: 1554-0200).

Keywords: Air Quality Index, Ascorbic Acid, Carotenoid, Chlorophyll.

Introduction

Urban air pollution has become a serious environmental problem to trees and crops (Chauhan and Joshi, 2008). Most of Indian cities are affecting with the presence of high concentrations of gaseous and particulate pollutants due to industrialization, badly maintained poor roads, poor maintenance of vehicles, uses of fuels with poor environmental performance and lack of awareness (Joshi and Chauhan, 2008). Ambient air pollution in several large cities of India is the amongst the highest in the world (Agrawal, 2005). According to an estimate, dust pollutants comprise around 40% of total air pollution problem in India (Chauhan and Sanjeev, 2008). The particulates and gaseous pollutants, alone and in combination, can cause serious setback to the overall physiology of Plants (Ashenden and Williams, 1980; Mejstrik, 1980; Anda, 1986; Seinfield, 1975). It has been reported that gaseous forms are absorbed by the leaves, while the particulate forms are absorbed through the outer surface of the plants. Affected plants shows some common effects such as chlorophyll, necrosis, inhibition in photosynthesis and decreasing plant growth (Davison and Blakemore, 1976).

Plant response to air pollution can be used to assess the quality of air that may provide early warning signals of air pollution trends (Wagh et al., 2006). Plants enormous 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), with a various extent for different species (Hove et al., 1999). Presence of trees in the urban environment can thus improve air quality through enhancing the uptake of gases and particles (McPherson et al., 1994; Beckett et al., 1998; Smith et al., 2005). Of all the plant parts, the leaf is the most sensitive part to air pollutants and several other such external factors (Lalman and Singh, 1990). Removal of pollutants by plant from air by three processes, namely deposition of particulates, absorption by leaves and aerosols over leaf surface (Prajapati and Tripathi, 2008).

Responses of plants towards air were assessed by air pollution tolerance index. Air pollution tolerance level of each is different and plants do not show a uniform behavior. It is seen that plant having higher index value are tolerant to air pollution and can be used as a filter of sink to mitigate pollution, while plants having low index value show less tolerance and can be used to indicate levels of air pollution. Several studies have shown the impact of automobile exhaust on roadside vegetation throughout their visible and non visible effects (Fleckiger et al., 1978; Keller, 1974; Leon, 1988; Joshi and Swami, 2007). Air pollutants like SO_2, NO_x, SPM and RSPM are responsible for reduction of biological and physiological responses of various plants and crops grown at polluted areas (Joshi and Chauhan, 2008; Chauhan and Joshi, 2008).

The present investigation has been undertaken to determine the effects of ambient particulate and gaseous pollutants on chlorophyll '*a*', '*b*', total chlorophyll, carotenoid, ascorbic acid, relatively humidity, pH and APTI (Air pollution tolerance index) trees grown at the famous Clock Tower of Dehradun, one of the main and busy road of the city, posses a high number of two wheelers, three wheelers and four wheelers vehicles throughout the day. Trees along the road side of site were selected for bio-physical analysis. Also, plants from pollution free atmosphere.

Material and Methods:

Study Sites:

Polluted site was located at roundabout of famous Clock Tower in Dehradun, while the control site was located at Tarla Naagal village, Sahastradhara Road, Dehradun, about 11 kms away from polluted site where pollution level is almost very low, posse's very dense forest and vegetations covers.

Air pollutants (SO_2, NO_x, SPM and RSPM) monitoring data at polluted site was obtained from State Pollution Control Board, Dehradun. However at the control site the concentration of air pollutants was measured with the help of RDS APM 460 by sucking air into appropriate reagent for 24 hours at every 30 days and after air monitoring it procured into lab and analysis for the concentration level. The SPM and RSPM were analyzed using Respirable Dust Sampler (RDS) APM 460 and operated at an average flow rate of 1.0-1.5 m^3 min^{-1}. Preweighed glass fiber filters (GF/A) of Whatman were used as per standard methods. SO_2 and NO_x were collected by bubbling the sample in a specific absorbing (sodium tetrachloromercuate of SO_2 and sodium hydroxide for NO_x) solution at an average flow rate of 0.2-0.5 min^{-1}. The impinger samples were put in ice boxes immediately after sampling and transferred to a refrigerator until analyzed. The concentration of NO_x was measured with standard method of Modified Jacobs- Hochheiser method (1958), SO_2 was measured by Modified West and Geake method (1956), SPM and RSPM using filter paper methods. The apparatus was kept at a height of 2 m from the surface of the ground. Using air pollutants data the air quality index was calculated. Leaves samples collected from both polluted and control sites. The chlorophyll '*a*', chlorophyll '*b*' and total chlorophyll were measured as per standard method of Maclachlan and Zalik (1963). Carotenoid was determined by the method of Duxbury and Yentsch (1956). Ascorbic acid was determined by the method of Sadashivam and Manikam, 1991. Ten samples of each of the tree species were analyzed on each sampling date. Similarly replicate samples and analytical blank were also analyzed to check the reliability of data. Relative Moisture Content by Weatherly (1965) and Air pollution tolerance index (APTI) was estimated using the method of Singh and Rao 1983. Leaf samples of selected trees were collected fortnightly during the study period from the Clock Tower (Polluted site) and also from the control site. These were weighed in a single pan electric balance (0.01mg accuracy) for measuring the dust content and then thoroughly washed with double distilled water for further analysis. AQI (air quality index) is calculated with air pollutants monitoring data by using the following equation (Rao & Rao, 1998).

$$\mathbf{AQI = 1/3\ [(SO_2)/Sso_2 + (NO_x)/S_{NOX} + SPM/S_{SPM}] \times 100}$$

Results

Air Pollutants

The concentration of air pollutants recorded has been presented in Table -1. Concentration of SPM at polluted site was 290.71, 285.47 and 199.04 μgm^{-3} during winter, monsoon and summer, respectively, whereas the standard limit prescribed by Central Pollution Control Board is 200 μgm^{-3} for residential area. RSPM recorded at polluted site was 133.07, 133.50 and 89.93 μgm^{-3} during winter, monsoon and summer, respectively, while the standard limit prescribed by CPCB of India is 100 μgm^{-3} for residential area. The highest concentration (26.61 μgm^{-3}) of SO_2 was recorded during monsoon reason at polluted site. Similarly highest concentration (27.92 μgm^{-3}) of NO_x was recorded during monsoon season at polluted site while the lowest concentration (26.97 μgm^{-3}) of NO_x was recorded during winter season at polluted site.

Chlorophyll pigments

Chlorophyll *a* and *b* contents in the leaf samples of *Ficus religiosa* were reported as 1.39±0.09 and 1.10±0.05 mg gm^{-1} at control site whereas these were 0.86±0.07 and 0.63±0.03 mg gm^{-1} respectively, at polluted sites. A decrease of 38.13% in chlorophyll *a* was recorded at polluted site in comparisons to control site, while a decrease of 42.73% in chlorophyll *b* was recorded at polluted site in comparison to control site. Total chlorophyll content recorded for *Ficus religiosa* was 2.49±0.85, and it was 1.49±0.08 mg gm^{-1} at control and polluted sites, respectively.

Chlorophyll *a* and *b* contents of *Mangifera indica* were reported as 2.98±0.09 and 1.98±0.08 mg gm^{-1} at control site and 2.38±0.12 and 1.59±0.14 mg gm^{-1} at polluted sites, respectively. A decrease of 20.13 and 19.70% was thus recorded in chlorophyll *a* and *b* contents at polluted site, respectively. Total chlorophyll content recorded at control and polluted sites was 4.49±0.15 and 3.97±0.55 mg gm^{-1}, respectively. There was a reduction of 11.58% in the total chlorophyll content in the leaf samples from the polluted site as compared to control site.

Chlorophyll *a* and *b* contents of *Polyalthia longifolia* were reported as 1.30±0.14 and 0.87±0.11 mg gm^{-1} at control and 0.94±0.40 and 0.61±0.08 mg gm^{-1} at polluted site, respectively. A decrease of 27.69 and 29.89% was recorded in chlorophyll *a* and *b* at polluted site, respectively. Total chlorophyll content recorded at polluted site for *Polyalthia longifolia* was 2.17±0.28 and it was 1.15±0.20 mg gm^{-1} at control site, a reduction of 47.00% in the total chlorophyll content of plant samples from polluted site as compared to control site was recorded.

Chlorophyll *a* and *b* contents of *Delonix regia* were reported as 1.67±0.12 and 1.07±0.09 mg gm^{-1} at control site and 1.04±0.09 and 0.80±0.12 mg gm^{-1} at polluted sites, respectively, with a decrease of 35.93 % and 21.05% in chlorophyll *a* and *b*, respectively. Total chlorophyll content recorded at control site was 2.71±0.15 mg gm^{-1} which was 1.87±0.13 mg gm^{-1} at polluted site, thus in this case there was reduction of 30.99% at the polluted site as compared to control site.

Carotenoid and ascorbic acid

Carotenoid contents of *Ficus religiosa* recorded at control and polluted site were 1.48±0.12 and 1.08±0.07 mg per gm, respectively. A decrease of 27.02% was thus recorded in the amount of carotenoid in the polluted site as compared to control site. Ascorbic acid content recorded was 1.43±0.09 and 0.87±0.06 mg per 100 gm at control and polluted sites, respectively. In this case there was a reduction of 39.16 % in ascorbic acid content of samples collected from polluted site as compared to control site.

Carotenoid of *Mangifera indica* recorded at control and polluted sites were 2.75±0.14 and 2.21±0.17 mg per gm, respectively. A decrease of 19.64 % was thus recorded in the amount of carotenoid in the polluted site as compared to control. Ascorbic acid content recorded was 2.14±0.13 and 1.67±0.12 mg per 100 gm at control and polluted sites, respectively. In this case there was a reduction of 21.96 % in ascorbic acid content of samples collected from polluted site as compared to control.

Carotenoid of *Polyalthia longifolia* recorded at control site was 1.39±0.13 and 0.96±0.16 mg per gm at polluted site. A decrease of 30.94 % was thus recorded in the amount of carotenoid in the polluted site as compared to control. Ascorbic acid content recorded was 1.31±0.08 and 1.03±0.09 mg per 100 gm at control and polluted sites, respectively. In this case there was a reduction of 21.38 % in ascorbic acid content of samples collected from polluted site as compared to control site.

Carotenoid of *Delonix regia* was recorded at control and polluted sites were 1.36±0.07 and 0.94±0.06 mg per gm, respectively. A decrease of 30.88 % was thus recorded in the amount of carotenoid in the polluted site as compared to control site. Ascorbic acid content recorded was 1.58±0.08 and 0.95±0.10 mg per 100 gm at control and polluted sites, respectively. In this case there was a reduction of 39.87 % in ascorbic acid content of samples collected from polluted site as compared to control site.

Relative moisture content, dust content, pH and APTI

Relative moisture content of *Ficus religiosa* leaves collected from control site was 69.16±4.81 % while it was 56.77±4.67 % at polluted site. Thus there was a reduction of 17.91 % in relative moisture content of samples collected from polluted site as compared to control. Amount of dust deposited on leaves was higher (0.43±0.03 mg per leaf) in control site in comparison to polluted site (0.10±0.02 mg per leaf). pH of leaves of control site was recorded as 7.56±0.17, where as pH of leaves sampled form polluted site was recorded as 6.41±0.18. Thus a change of 15.21 % toward the acidic side was recorded in the samples collected from polluted site. Air pollution tolerance index of *Ficus religiosa* was determined as 8.35±0.13 and 6.36±0.17 at control and polluted sites, respectively.

Relative moisture content of *Mangifera indica* leaves was higher (58.88±3.88 %) in the plant samples collected from control site as compared to samples collected from polluted (42.89 %) site. Amount of dust deposited on leaves was higher (0.50±0.02 mg per leaf) in polluted site in comparison to control site (0.08±0.01 mg per leaf). pH of leaves of control site was recorded as 6.89±0.19, where as pH of leaves sampled form polluted site was recorded as 5.98±0.23. Thus a change of 13.21 % toward the acidic side was recorded in the samples collected from polluted site. Air pollution tolerance index of *Mangifera indica* was determined as 8.32±0.12 and 5.95±0.14 polluted site.

Relative moisture content *Polyalthia longifolia* was higher by 16.60 % in the plant samples collected from control site. The amount of dust deposited on leaves was higher (0.40±0.05 mg per leaf) in polluted site in comparison to control site (0.07±0.04 mg per leaf). pH of leaf of control site was recorded as 6.39±0.17 , where as pH of leaf sampled from polluted site was recorded as 5.62±0.20. Thus a change of 12.05 % towards the acidic side was recorded in the samples collected from polluted site. Air pollution tolerance index of *Polyalthia longifolia* was determined as 7.08±0.13 and 5.57±0.18 at control and polluted sites, respectively.

Relative moisture of *Delonix regia* was recorded at control site was 73.67±4.56 % whereas it was 60.89±4.67 % at polluted site. Thus there was a reduction of 17.35% in relative moisture content of samples collected from polluted site as compared to control site. Amount of dust deposited on leaves was higher (0.37±0.06 mg per leaf) in polluted site in comparison to control site (0.08±0.04 mg per leaf). pH of leaves collected from control site was recorded as 6.89±0.31, where as pH of leaves sampled form polluted site was recorded as 5.61±0.27. Thus a change of 18.57 % toward the acidic side was recorded in the samples collected from polluted site. Air pollution tolerance index of *Delonix regia* was determined as 8.73±0.17 and 6.70±0.23 at control and polluted sites, respectively.

Table 1: Primary Air Pollutants Recorded From Control And Polluted Sites During The Study Period

	NO_X (μgm^{-3})			SO_2 (μgm^{-3})			SPM (μgm^{-3})			RSPM (μgm^{-3})			AQI		
Site	Winter	Monsoon	Summer	Winter	Monsoon	Summer	Winter	Monsoon	Summer	Winter	Monsoon	Summer	Winter	Monsoon	Summer
P	26.97	27.92	27.02	25.57	26.61	25.14	290.71	285.47	199.04	133.07	133.50	89.93	70.34	70.76	54.91
C	2.21	1.92	2.05	1.62	1.51	1.84	91.15	80.14	75.57	33.12	34.22	29.52	16.79	14.79	14.22
(24 hr)	80.00 $\mu g\ m^{-3}$			80.00 $\mu g\ m^{-3}$			200.00 $\mu g\ m^{-3}$			100.00 $\mu g\ m^{-3}$			CPCB standard		

Where**:** SPM = Suspended particulate matte, RSPM = Respirable suspended particulate matter, CPCB= Central Pollution Control Board, New Delhi, India, P= Polluted Site, C= Control Site.

Table -2: Rating Scale Of AQI Values At Polluted And Control Sites

Index value	**Remarks**	**Polluted Site**			**Control Site**		
		Winter	**Monsoon**	**Summer**	**Winter**	**Monsoon**	**Summer**
0-25	Clean air (CA)						
26-50	Light air pollution (LAP)	MAP	MAP	MAP	CA	CA	CA
51-75	Moderate air pollution (MAP)						
76-100	Heavy air pollution (HAP)						
>100	Severe air pollution (SAP)						

Where: W= Winter, M= Monsoon, S= Summer

Table 3. Changes In The Physical And Bio-Chemical Characteristics Of Tree Species Due To Auto Exhaust Emission.

Parameters	***Ficus religiosia***		***Mangifera indica***		***Polyalthia longifolia***		***Delonix regia***	
	C	**P**	**C**	**P**	**C**	**P**	**C**	**P**
Chlorophyll *a* (mg/g)	1.39±0.09	0.86±0.07***	2.98±0.09	2.38±0.12***	1.30±0.14	0.94±0.40***	1.67±0.12	1.07±0.09***
Chlorophyll *b* (mg/g)	1.10±0.05	0.63±0.03***	1.98±0.08	1.59±0.14***	0.87±0.11	0.61±0.08***	1.04±0.45	0.80±0.12***

Total Chlorophyll (mg/g)	2.49±0.85	1.49±0.08***	4.49±1.15	3.97±0.55***	2.17±0.28	1.15±0.20***	2.71±0.15	1.87±0.13***
Carotenoid (mg/gm)	1.48±0.12	1.08±0.07***	2.75±0.14	2.21±0.17***	1.39±0.13	0.96±0.16***	1.36±0.07	0.94±0.06***
Ascorbic Acid (mg/100gm)	1.43±0.09	0.87±0.06***	2.14±0.13	1.67±0.12***	1.31±0.08	1.03±0.09***	1.58±0.08	0.95±0.10***
Relative moisture content (%)	69.16±4.81	56.77±4.67***	58.88±3.88	42.89±3.91***	59.58±2.86	48.69±3.12***	73.67±4.56	60.89±4.67***
Dust deposited (mg/leaf)	0.10±0.02	0.43±0.03**	0.08±0.01	0.50±0.02***	0.07±0.04	0.40±0.05**	0.08±0.04	0.37±0.06*
pH	7.56±0.17	6.41±0.18***	6.89±0.19	5.98±0.23***	6.39±0.17	5.62±0.20***	6.89±0.31	5.61±0.27***
APTI	8.35±0.13	6.36±0.17***	8.32±0.12	5.95±0.14***	7.08±0.13	5.57±0.18***	8.73±0.17	6.70±0.23***

Significant at: *p <0.05, **p<0.01, ***p<0.001, C = control site, P = polluted site

Discussion

Chlorophyll and carotenoid both takes part in photosynthetic reaction. The different pollutants play a significant role in inhibition of photosynthetic activity that may results in depletion of chlorophyll and carotenoid content of the leaves of various plants (Chauhan and Joshi, 2008). Highest decrease in chlorophyll '*a'* content of the samples collected from polluted site in comparison with control sites was thus recorded in *Ficus religiosa* (38.18) whereas lowest was for *Mangifera indica* (20.13 %). Two-way ANOVA shows that reduction in chlorophyll '*a'*, chlorophyll '*b'* and total chlorophyll contents of *Ficus religiosa*, *Mangifera indica*, *Polyalthia longifolia* and *Delonix regia* were significant at 0.001 % level. The reductions in chlorophyll '*a'*, chlorophyll '*b'* and total chlorophyll due to air pollution have been noted (Joshi and Chauhan, 2008). Rao and Leblanc (1966) have also reported reduction in chlorophyll content brought by acidic pollutants like SO_2 which causes phaeophytin formation by acidification of chlorophyll. Several studies with higher plants exposed to different SO_2 concentrations show decreases in chlorophyll contend (Inglis and Hill, 1974; Hallgren and Huss, 1975; De Santo et al., 1979; Agrawal and Rao, 1982).

Highest decreases in carotenoid content was reported for *Polyalthia longifolia* (30.94%) while lowest decreases in *Mangifera indica* (19.64 %). Two-way ANOVA shows significant reductions in all selected tree species were significant at 0.001 % level. Carotenoids are a class of natural fat-soluble pigments found principally in plants, algae and photosynthetic bacteria, where they play a critical role in photosynthesis (Ong and Tee, 1992). Carotenoid protects chlorophyll from photoxidative destruction (Siefermann-Harms, 1987). The carotenoid contents of some crop plants were found to decrease in response to SO_2 (Pandey, 1978; Singh, 1981; Nandi, 1984). It also been noted that carotenoids are more sensitive to SO_2 than chlorophyll (Shmimazaki et al., 1980).

Two-way ANOVA shows the decline in ascorbic acid content in all four plant species were significant at 0.001% level. Highest reduction in ascorbic acid content was observed for *Delonix regia* (39.87 %) and lowest reduction for *Polyalthia longifolia* (21.37 %). Ascorbic acid, a natural antioxidant in plants plays significant role in pollution tolerance (Chen et al., 1990).

Relative moisture content of all four tree species was significant at 0.001 % level using two-way ANOVA. A high water content with a plant body may help to maintain its physiological balance under air pollution stress condition. High relative water content favors resistance in plants (Dedio, 1975). Highest changes in dust content were found in Mangifera indica and lowest found in *Ficus religiosa*. *Ficus religiosa* and *Polyalthia longifolia* were significant at 0.01 % level and *Delonix regia* and *Mangifera indica* were significant at 0.05 % and 0.001% level, respectively.

The change in pH in the leaf sample collected from polluted site was significant at 0.001%

level in four tree species. All the plant samples collected from polluted site exhibited a pH towards acidic side, which may be due to the presence of SO_2 and NO_x in the ambient air causing a change in pH of the leaf sap towards acidic site (Swami et al., 2004). Two-way ANOVA show that reduction in APTI of all four tree species was significant at 0.001 % level. Air pollution tolerant index is an index denotes capability of a plant to combat against air pollution. Plants which have higher index value are tolerant to air pollution and can be caused as sink to mitigate pollution, while plants with low index value show less tolerance and can be used to indicate levels of air pollution (Singh and Rao, 1983).

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