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Air pollution induced changes in the photosynthetic pigments of selected plant species

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Abstract: *Changes in the concentration of different photosynthetic pigments (Chlorophyll and carotenoids) were determined in the leaves of six tree species exposed to air pollution due to vehicular emissions. The six tree species, which are all economically important because of their being fruit bearers, used for timber, fodder and as road side trees on the basis of their air pollution tolerance index. These included Mangifera indica L., Tectona grandis Linn.f., Shorea robusta Gaertn.f., Holoptelea integrifolia (Roxb.) Planch, Eucalyptus citridora Hook. Syn. and Mallotus philippinensis Muell-Arg. Reduction in chlorophyll 'a', 'b' and carotenoid was recorded in the leaf samples collected from polluted areas when compared with samples from control areas. The highest reduction in total chlorophyll was observed in Holoptelea integrifolia (Roxb.) (48.73%) Planch whereas, the lowest reduction (17.84 %) was recorded in Mallotus philippinensis Muell-Arg. Similarly in case of carotenoid contents, highest reduction (43.02 %) was observed in Eucalyptus citridora, and lowest in Mallotus philippinensis Muell-Arg (19.31 %). The data obtained were further analyzed using one-way ANOVA and a significant change was recorded in the studied parameters. These studies clearly indicate that the vehicular induced air pollution reduces the concentration of photosynthetic pigments in the trees exposed to road side pollution*

Key words: *Automobile emissions, Photosynthetic pigments, Chlorophyll, Carotenoids*
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Introduction

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. Demand of rapid modes of transportation has increased many folds during the last few decades because of the continuous rise in the human population. This in turn has led a tremendous increase in the number of different types of vehicles, which now has become a major source of air pollution throughout the world. The use of automobiles is growing fast, globally at large and with much greater pace in developing countries. The annual compound growth rate in the last 5 years in the automobile sector is estimated to be + 12 % per annum. About 19 million vehicles are added each year to the global total (Uppal, 1988). In India, vehicles fleets are poorly maintained, roads are narrow and number of vehicles with two stroke engines is high, thus increasing the significance of motor vehicles as a source of pollutants (Pandey and Pandey, 1996). In fact, vehicular pollution is much greater than that caused by the emission of dust and poisonous gases by different types of factories. Motor vehicles account for 60-70% of the pollution found in an urban environment (Singh *et al*., 1995; Tripathi and Gautam, 2007; Dwivedi *et al.,* 2008). The combustion of fuel in engines of motor gives rise to sulphur dioxide (SO_2), nitrogen oxides (NO_x) and CO, as well as suspended particulate matter. These pollutants when absorbed by the leaves cause a reduction in the concentration of photosynthetic pigments *viz.*, chlorophyll and carotenoids, which directly affect to the plant productivity. Chlorophyll is the principal photoreceptor in photosynthesis, the light-driven process in which carbon dioxide is "fixed" to yield carbohydrates and oxygen. Carotenoids are a class of natural fat-soluble pigments found principally in plants, algae and photosynthetic bacteria, where they play a critical role in the photosynthetic process (Ong and Tee, 1992; Britton, 1995) and also protect chlorophyll from photoxidative destruction (Siefermann-Harms, 1987). When plants are exposed to the environmental pollution above the normal physiologically acceptable range, photosynthesis gets inactivated (Mizalski and Mydlarz, 1990).

Studies on the effects of air pollutants due to automobiles on morphology, physiology and biochemistry of plants have been carried out by a number of workers (Treshow, 1985; Kozial and Whately, 1984; Ahmed *et al*., 1988; Salgere and Nath, 1991; Raina and Agarwal, 2004; Tripathi and Gautam, 2007), in the different parts of the world. According to a study by Dwivedi and Tripathi (2007), 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 (Wagh *et al.,* 2006). Leaf chlorophyll content and carotenoids thus can provide valuable information about physiological status of plants. Present study has been carried out to know the changes in the concentration of chlorophyll and carotenoids in the leaf samples of the plants exposed to roadside automobile pollution.

Materials and Methods

Study sites and sampling procedure: Haridwar, located in the state of Uttarakhand, is one of the important holy cities of India and is extended from latitude 29° 58' in the north to longitude 78°13' in the east 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. Being in the foot hills of the State Government has developed the State Industrial

Development Corporation Ltd., in the City and some 540 industries are expected to be established in the area. This has further increased the load of vehicular concentration on the roads of Haridwar. These vehicles emit lots of harmful gases in the environment which directly affect to living organisms and plants exposed to it, especially to road side plants which remain in direct contact of this type of pollutants.

The present study was conducted at different sites situated along the Rishikesh – Roorkee Highway No. 58 during 2005-06. The vehicular concentration of heavy vehicles, light vehicles, cars and two-wheelers was recorded at different sampling sites on each of the sampling day and an average of 8 hr count was calculated, which comes about 25 vehicles per minute. All the sites are 8 km apart from each other, so the study area envisaged around 32 km.

The tree species of *Mangifera indica* L., *Tectona grandis* Linn.f., *Shorea robusta* Gaertn.f., *Holoptelea integrifolia* (Roxb.) Planch, *Eucalyptus citridora* Hook. Syn. and *Mallotus philippinensis* Muell-Arg, selected in the present study are grown all along the road side between Roorkee and Rishikesh. These have air pollution tolerence index (APTI) less than 10, and are termed as sensitive species, which can be used for biomonitoring of air pollutants (Agrawal *et al.,* 1991). Leaf samples of selected trees were collected fortnightly during the study period from the edge of the road (Polluted site) and 100 m far away from the edge of the road (Control site). On each sampling day 50 samples were collected from five replicating individuals of each species. 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. The estimation of photosynthetic pigments (chlorophyll and carotenoids) was done according to the method proposed by Arnon (1949).

Samples of air pollutants were also collected fortnightly with the help of Respiratory Dust Sampler (APM-415) from each site, where plant sampling was done. The apparatus was kept at a height of 2 m from the surface of the ground. For the collection of samples of SPM at each sampling site, GF/A filter paper was used. It was weighed before and after sampling. Air quality monitoring of gaseous pollutants *viz.*, SO_2 and NO_x was carried out using the methods of West and Gaeke (1956) and Jacob and Hochheiser (1958), respectively. All the data obtained were further analyzed by using one-way ANOVA.

Results and Discussion

Seasonal variation in the concentration of air pollutants has been given in Table 1. The concentration of RSPM was highest (150.00 μg m^{-3}) during the summer season, while the SPM was highest (401.00 μg m^{-3}) during the winter season. The concentration of sulpher dioxide at polluted site was highest (10.21 μg m^{-3}) during summer season, which was 38.12% higher as compared to control site. The highest concentration of NO_x (20.33 μg m^{-3}) was also recorded during the summer season at the polluted sites, which was again 29.19% higher as compared to control site.

The concentration of different photosynthetic pigments recorded for the selected plant species collected from polluted and control sites have been presented in the Table 2.

***Tectona grandis* Linn.f.:** The concentration of chlorophyll ‘a’ content in the leaves of *Tectona grandis* at polluted sites was recorded as 1.02 ± 0.15 mg g^{-1}, which was 1.23 ± 0.12 mg g^{-1} at controls site. Thus a reduction of 17.07% in chlorophyll ‘a’ content was recorded in the samples from polluted sites in comparison to control site. The concentration of chlorophyll ‘b’ content was 0.59 ± 0.24 mg g^{-1} in the leaf samples collected from polluted sites while it was 0.87 ± 0.15 mg g^{-1} in the samples from control site. The polluted sites samples thus had 32.18% less chlorophyll ‘b’ content total chlorophyll content was 1.61 ± 0.11 mg g^{-1} and 2.10 ± 0.33 mg g^{-1} in the leaf samples collected from polluted and control site respectively. Thus there was a reduction of 23.33% in the concentration of total chlorophyll content in the samples from polluted sites. The concentration of carotenoid pigment in the leaf samples from polluted and control site were recorded as 1.20 ± 0.23 mg g^{-1} and 2.00 ± 0.44 mg g^{-1}, respectively with a reduction of 40% in the leaf samples from polluted sites.

***Shorea robusta* Gaertn. F.:** In case of *Shorea robusta* Gaertn. F the reduction recorded was 28.57% in chlorophyll ‘a’ content, 20.00% in chlorophyll ‘b’ content, 25.80% in total chlorophyll and 23.33% in the concentration of caratenoids in the leaf samples collected from polluted sites.

***Holoptelea integrifolia* (Roxb.) Planch:** The concentration of chlorophyll ‘a’ ‘b’, total chlorophyll and carotenoids was less by 20.00, 89.79, 48.73 and 27.63%, respectively, in leaves sampled from polluted sites in comparison to leaves sampled from control site.

***Eucalyptus citridora* Hook, Syn.:** The reduction recorded in the leaves of *Eucalyptus citridor* sampled from polluted sites was 26.89, 79.24, 43.02 and 43.02% for chlorophyll ‘a’, ‘b’, total chlorophyll and carotenoids, respectively.

***Mallotus philippinensis* Muell-Arg.:** In *Mallotus philippinensis* Muell-Arg, chlorophyll ‘a’ was 15.92%, chlorophyll ‘b’ was 20%, total chlorophyll was 17.84% and carotenoids were 19.31% less in the leaf samples collected from polluted sites.

***Mangifera indica* L.:** A reduction in the concentration of different pigments was also recorded in the leaf samples collected from polluted sites in comparison to samples from control sites which was 10.52, 88, 43.77 and 22.30% for chlorophyll ‘a’, ‘b’, total chlorophyll and carotenoids, respectively.

During the present study the concentration of RSPM and SPM is recorded very high as compared to the prescribed standards of National Ambient Air Quality Standards(CPCB, 1995), which are 75 μg m^{-3} and 100 μg m^{-3} in the sensitive areas and 100 μgm^{-3} and 200 μg m^{-3} for the industrial areas, respectively. The concentration of SO_2 is higher in air samples collected from the polluted site, however, it is less than the prescribed values by the NAAQS, which is 30 μg m^{-3} for the sensitive areas and 80 μg m^{-3} for the residential areas. Similarly the concentration of NO_x is less than the prescribed

Table - 1: Primary air pollutants recorded from control and polluted sites (average of 24 readings) during the study period (2005-06)

Sites	RSPM (µg m^{-3})			SPM (µg m^{-3})			NO_x(µg m^{-3})			SO_x (µg m^{-3})		
	Winter	Monsoon	Summer	Winter	Monsoon	Summer	Winter	Monsoon	Summer	Winter	Monsoon	Summer
Polluted site	122.00	128.40	150.00	401.00	350.22	363.12	12.18	10.22	20.33	7.62	6.11	10.21
Control site	81.00	96.02	97.15	288.48	215.00	297.45	10.16	9.45	14.39	5.20	4.33	6.31
% higher at polluted site	33.60	25.21	32.23	28.05	38.61	18.08	16.58	7.53	29.19	37.69	29.13	38.19

Where: RSPM = Respirable particulate matter, SPM = Suspended particulate matter

Table - 2: Concentration of different photosynthetic pigments (mg g^{-1}) in the leaves of selected tree species collected from polluted and control areas

Tree species	Parameters											
	Chlorophyll 'a'			Chlorophyll 'b'			Total chlorophyll			Carotenoids mg g^{-1}		
	Polluted	Control	% R	Polluted	Control	% R	Polluted	Control	% R	Polluted	Control	% R
Tectona grandis Linn.f.	1.02 ** ± 0.15	1.23 ± 0.12	17.07	0.59 ns ± 0.24	0.87 ± 0.15	32.18	1.61 *** ± 0.11	2.10 ± 0.33	23.33	1.20 ns ± 0.23	2.00 ± 0.44	40.00
Shorea robusta Gaertn.f.	1.50 ** ± 0.28	2.10 ± 0.16	28.57	0.80 ** ± 0.22	1.00 ± 0.11	20.00	2.30 *** ± 0.54	3.10 ± 0.22	25.80	1.15 ns ± 0.21	1.50 ± 0.27	23.33
Holoptelea integrifolia (Roxb.) Planch	1.12 ns ± 0.11	1.40 ± 0.28	20.00	0.10 ns ± 0.11	0.98 ± 0.23	89.79	1.22 ** ± 0.17	2.38 ± 0.50	48.73	1.10 ns ± 0.28	1.52 ± 0.30	27.63
Eucalyptus citridora Hook. Syn.	0.87 ns ± 0.23	1.19 ± 0.08	26.89	0.11 ns ± 0.21	0.53 ± 0.15	79.24	0.98 ns ± 0.11	1.72 ± 0.27	43.02	0.98 ns ± 0.12	1.72 ± 0.23	43.02
Mallotus philippinensis Muell-Arg.	0.95 ** ± 0.10	1.13 ± 0.07	15.92	0.80 ns ± 0.29	1.00 ± 0.19	20.00	1.75 ** ± 0.28	2.13 ± 0.14	17.84	1.17 ns ± 0.20	1.45 ± 0.24	19.31
Mangifera indica L.	1.19 ** ± 0.10	1.33 ± 0.12	10.52	0.12 ** ± 0.11	1.00 ± 0.17	88.00	1.31 ns ± 0.20	2.33 ± 0.11	43.77	1.08 ns ± 0.33	1.39 ± 0.24	22.30

Where: % R = Percentage reduction, ** and *** indicate least significant difference at $p < 0.05\%$ and $p<0.01\%$ level respectively, ns = non-significant

concentrations for sensitive and residential areas, which in this case is again 30 µg m^{-3} and 80 µg m^{-3} respectively.

The vehicular emissions have a profound impact on the concentration of different photosynthetic pigments. 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 (Mark, 1963; Singh and Rao, 1981). Similar reduction has been recorded in the leaves of *Pinus hallepensis* (Thmislav and Ledic, 1992). Damage in chlorophyll content in *R. ecklonii* (Spreng.) Mey. planted in heavy traffic road sites has also been recorded by Garty *et al*., 1985). Dusted or encrusted leaf surface is responsible for reduced photosynthesis and thereby causing reduction in chlorophyll content (Mishra and Gupta, 1993). The similar impact of air pollutants on the concentration of chlorophyll contents have been reported by a number of other workers (Nikova and Dushkova, 1978; Rabe and Kareeb, 1979; Dubey and Pawar, 1985; Saha *et al.,* 1986; Saxena, 1991; Swami *et al.*, 2004;Tripathi and Gautam, 2007). In the present study the highest decrease in total chlorophyll was in *Holoptelea integrifolia* (48.735) followed by *Mangifera indica* (43.77%), *Eucalyptus citridora* (43.02), *Shorea robusta* (25.80%),*Tectona grandis* (23.33%) and *Mallotus philippinensis* (17.84%). The one way ANOVA shows that the reduction in chlorophyll contents of *S. robusta* and *T. grandis* were significant at 0.01% level. The reason for degradation of chlorophyll pigments can also be attributed to action of SO_2 and NO_2 on the metabolism of chlorophyll (Lauenorth and Dodd, 1981), both of these gases are the constituents of vehicular emissions. The reduction in the concentration of chlorophyll might have also been caused due to the increase in chloophyllase enzyme activities, which in turn affects the chlorophyll concentration in plants (Mandal and Mukherji, 2000). Our results are also in agreement with the work of Wali *et al.* (2004)*,* who have reported that the chlorophyll was significantly low in the plants fumigated with different levels of SO_2 and Chlorophyll *a* being more severely affected than chlorophyll *b.* Chlorophyll *a* is degraded to phaeophytin through replacement of Mg^{+2} ions in chlorophyll molecules, while chlorophyll b forms chlorophyllide b through the removal of phytol group of the molecule (Rao and Le Blane, 1966).

Plant carotenoids are red, orange and yellow lipid soluble pigments found embedded in the membranes of chloroplast and chromoplast. Carotenoids protect photosynthetic organisms against potentially harmful photoxidative processes and are essential structural components of the photosynthetic antenna and reaction center (Bartley and Scolonk, 1995). They play pivot role as accessory plant pigments. During the present study decrease in carotenoids content at polluted site in comparison to control was highest in *Eucalyptus citridora* (43.02%) and lowest in *Mallotus philippinensis* (19.31%). Agarwal and Sharma (1984) have reported significant reduction in carotenoid pigments in leaf samples collected form polluted environment. Swami *et al.* (2004) have also reported significant reduction in carotenoid contents in *Shorea robusta* and *Mallotus phillipinensis,* due to road side automobile emission. Similarly, Agrawal (1985) have reported more than additive reduction in carotenoids content of a variety of plants due to their exposure to gaseous air pollutants. Aquil *et al.* (2003) have also reported a reduction in carotenoids content in the plants of *Albizzia lebbek* Benthdue exposed to coal smoke.

It is evident from the above discussion that the pollutants such as RSPM, SPM, SO_2 and NO_2 from automobile exhaust not only cause bad air quality condition around nearby areas but also cause significant reduction in chlorophyll pigments.

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