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Effect of automobile pollution on chlorophyll content of roadside urban trees

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ABSTRACT: The effect of automobile pollution was determined on chlorophyll content of four different tree species viz. *Azadirachta indica* L., *Conocarpus erectus* L., *Guiacum officinale* L. and *Eucalyptus* sp. growing along the roads of the city. Significant changes in the level of chlorophyll "a", chlorophyll "b" and total chlorophyll "a+b" were found in the leaves of four tree species (*A. indica, C. erectus, G.officinale* and *Eucalyptus* sp.) collected from polluted sites (Airport, Malir Halt, Quaidabad) as compared to control site (Karachi University Campus). Lowest concentration of chlorophyll "a", chlorophyll "b" and chlorophyll "a+b" was recorded in the leaf samples of all tree species collected from Quaidabad site when compared with the leaf samples collected from control site. The highest levels of chlorophyll pigment were recorded in all tree species leave samples collected from Karachi University Campus. Similarly, better levels of chlorophyll "a", chlorophyll "b" and total chlorophyll "a+b" was observed in all tree species growing at Airport site as compared to plants growing at Malir Halt and Quaidabad sites. This study clearly indicated that the vehicular activities induced air pollution problem and affected on the level of chlorophyll pigments in trees which were exposed to road side pollution.

Keywords: Automobiles; Chlorophyll pigment content; Road side pollution; Urban trees.

INTRODUCTION

Motor vehicles account for the world's air pollution more than any other human activity. They are responsible for virtually all of the carbon monoxide and lead in the air of cities, and a major portion of the NOx, VOCs (Volatile organic compounds), fine particles, and toxic chemicals (Durrani *et al.*, 2004; Chauhan, 2010; Narwaria and Kush, 2012). The transport system of Karachi city consists on buses, minibuses, trucks, wagons, vans, Suzuki, auto rickshaws and motor cycles. Faulty and badly maintained automobile vehicles release carbon particles, unburned and partially burned hydrocarbons, tar materials, lead compounds and other elements in the environment due to incomplete combustion of fuel which are the constituents of petrol and lubricating oils deposited on the surface of plants.

These pollutants in combinations cause greater or synergistic effects to plants growth. The deposition of trace elements, gaseous pollutants, nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2) on the leaves affected their physiological behavior (Wittenberghe *et al.*, 2013).

In last couple of decades, it has been observed with great concern that the density of vehicles in the city of Karachi have increased enormously. Many adverse effects of automobile pollution on plants growing along the busy roads have been observed. The nature of harmful effects can vary to some extents, depending on the pollutant and tolerance of the species. Pollutants

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discharged from automobiles are expected to have major effects on phenology, periodicity, fruiting, flower development, leaf senescence and leaf surface wax characteristics, biomass production, seed germination, seedling growth, physiological and biochemical characteristics and plant growth (Iqbal and Siddiqui, 1996; Iqbal *et al.,* 1997; Aksoy and Sahln, 1999; Iqbal and Shafiq, 1999; Aksoy *et al.,* 2000; Wagh *et al.,* 2006; Prajapati *et al.,* 2008; Shafiq and Iqbal, 2007, 2012; Honour *et al.,* 2009; Narwaria and Kush, 2012; Leghari *et al.,* 2013; Parveen *et al.,* 2014). Environmental degradation, destruction of trees and green areas to accommodate urban development are responsible for shortening the life span of trees (Philip and Azlin, 2005; Wagh *et al.,* 2006; Joshi and Swami 2007, 2009).

Chlorophyll is the green molecule in plant cells that carries out the bulk of energy fixation in the process of photosynthesis. In photosynthesis, sunlight is absorbed by chlorophyll. Actually, chlorophyll itself is not a single molecule, but a family of related molecules designated as chlorophyll a, b, c and d. (Bignal *et al.,* 2008). Chlorophyll plays a crucial role in photosynthesis (Sadaoka *et al.,* 2011). Pollution from automobiles normally comes from engine fumes, due to incomplete burning of fuel. It is well known that air pollution represents a threat to both the environment and human health, and it is estimated that millions of tons of toxic pollutants are released into air each year (Rai, 2013). Chlorophyll catabolism not only affects the key components of a plant's photosynthesis systems, but it is also responsible for the green color of leaves and fruits and therefore, it plays an important role in plant development. (Peng *et al.,* 2013).

Air pollution from road transport is of continuing concern and motor vehicles emit a cocktail of pollutants. There is little information available concerning the effects of automobile pollutants on plant growth in roadside habitats of Karachi. Four tree species growing adjacent to busy roads of the city were selected for the study. Quantification of chlorophyll content provides useful insights into the physiological performance of plants (Girma *et al.,* 2013). In our previous studies, automobile exhaust significantly reduced the branch length and yield of *Guaiacum officinale, Azadirachta indica* and *Eucalyptus sp*. The yield of *Azadirachta indica, Eucalyptus sp.*and *Guaiacum officinale* was lessened at the polluted sites of the city. The increase in branch length of all the species was found mainly in control as compared to polluted sites (Iqbal and Shafiq, 2000). Little is known about the effects of automobile pollution on chlorophyll concentration of plants growing in the polluted environment of Karachi city. The aim of the present research was to investigate the effects of automobile pollution on chlorophyll level of some common trees (*Azadirachta indica, Conocarpus erectus, Guiacum officinale* and *Eucalyptus* sp.) growing along the roads of Karachi city. These species are continuously under the exposure of autovehicular exhaust emission pollution.

This study has been performed in Karachi city during 2014.

MATERIALS AND METHODS

Species description

Azadirachta indica A. Juss. is a drought tolerant species belonging to the family of Meliaceae, successfully grown to prevent soil erosion and helping in soil management. *A. indica* is cultivated in many areas and easily dominates in natural plant communities. The tree is cultivated in warmer parts of the country. It yields good timber and all parts of the plant are medicinal. *Conocarpus erectus* L., (green button wood) belongs to Combretaceae family and is an evergreen tree having a spreading crown. *C. erectus* widely grown as cultivated. *Guiacum officinale* L. is a member of Zygophyllaceae family and found as ornamental in central and northern South America. *G. officinale* is an ornamental plant successfully planted in gardens in many parts of Pakistan. *G. officinale* commonly known as lignumvitae (English), guayac' (Spanish), and bois de gaoac (French), is a beautiful, small to medium sized tree of dry tropical forests (Francis, 1993). *Eucalyptus sp.* belongs to the family Myrtaceae, hardy, a large cultivated tree which grows rapidly.

Site description

Karachi is the largest industrial city of Pakistan, situated on the coast along the Arabian Sea. The climate of Karachi is subtropical maritime desert, whereas the bioclimate of Karachi falls under the category of tropical desert bush formation. Average wind velocity is 12 m/s during June and July and 3.5 m/s from January to March. During the southwest monsoon season winds blow from the sea towards the coast, whereas during the northeast monsoon their direction is reversed. Therefore, pollutants are pushed inland during the southwest monsoon season and are blown out to sea during the northeast monsoons (UNEP, 1992). The hot and humid rainy season which is variable, lasts from June to September. The winter season is very short lasting from middle of November to middle of February. The rest of the months constitute the summer, autumn and spring seasons. The temperature is mild with no frost. The dew formation is quite common, the relative humidity is high and the differences in day and night temperatures are great. The climatic and edaphic conditions at Karachi University Campus are not different from other sites of the city.

Selection of sites

The site in urban area is disturbed mainly by autovehicular activities, including all main traffic networks (Airport, Malir Halt, Quaidabad) whereas Karachi University Campus is relatively a clean area. The direction and distance was noted with the help of Google maps and brief description of the study area is given below:

Karachi University Campus

Karachi University Campus is situated at the outskirts of the city. This site is relatively free from the autovehicular activities as compared to other sites of the city. Karachi University Campus is 12 km away from Quaid-e-Azam tomb.

Airport

Airport is located about 18 kms east of the Quaid-e-Azam tomb. This place is comparatively open with low traffic.

Malir Halt

Malir Halt handles a large traffic volume, moving from north and south to east of the city. This site is about 20 km away from the east of Quaid-e-Azam tomb.

Quaidabad

Quaidabad has many multi-storied buildings. This site is 23 kms from the eastern site of the Quaid-e-Azam tomb and it is heavily influenced by traffic activities. This site is the most congested site. This site serves as a national highway and traffic moves to upside of the country. The slow movement of traffic starts building up toxic pollutants in the area.

Sample collection and chlorophyll analysis

The fresh leaves sample of four tree species (*Azadirachta indica*, *Conocarpus erectus*, *Guiacum officinale* and *Eucalyptus* sp.) were collected from the polluted sites (Airport, Malir Halt, Quaidabad) and the control site (Karachi University Campus) of the city of Karachi. Sufficient quantities of leaf samples were kept in labeled sample bags for chemical analysis. As expected, the three sites differed in exposure to automobile pollution conditions due to variation in traffic density. All the determinations were obtained with randomly chosen leave samples. Chlorophyll was extracted from the leaves of all tree species and was estimated by the method of Maclachlam and Zalik (1963). One gram of fresh leaf samples were macerated in 10ml of 80% (v/v) acetone and centrifuged at 1000 rpms for 10 minutes to clear the suspension supernatant, which contained soluble pigment and was used for the determination of chlorophyll. One ml of solution was used for detection of chlorophyll content by spectrophotometer, absorbance of the extract was recorded at 663 and 645nm on spectrophotometer against 80% (v/v) acetone blank. The chlorophyll content was calculated using the formula given below and expressed in mg/g fresh weight.

Chlorophyll “a” mg/g =

$$(12.3D663 - 0.861D645 / d \times 1000 \times W) \times V$$

Chlorophyll “b” mg/g =

$$(19.3D645 - 3.6D663 / d \times 1000 \times W) \times V$$

Where:
D663 = absorbance at 663nm
D645 = absorbance at 663nm
W = fresh weigh of leaf sample taken (1 g)
d = length of light path in cm
V = volume of leaf extract (10 ml).

Calculations for determination of chlorophyll “a”, chlorophyll “b” and total chlorophyll “a+b” were conducted according to following equations.

Chlorophyll “a” mg/g =0.0127 A663 – 0.00269 A645
Chlorophyll “b” mg/g =0.0029 A663 – 0.00468 A645

Total Chlorophyll “a+b”

Average chlorophyll “a” + Average chlorophyll “b” mg/g =0.0202 A663 + 0.00802 A645

The data obtained were subjected to one-way Analysis of Variance (ANOVA) using COSTAT Statistical Package version 03 and mean separation was done according to Duncan Multiple Range Test at $p<0.05$ on a personal computer.

RESULTS AND DISCUSSION

The effects of automobile pollution on chlorophyll content of all tree species (*Azadirachta indica*, *Conocarpus erectus*, *Guiacum officinale* and *Eucalyptus* sp.) growing at polluted sites (Airport, Malir Halt, Quaidabad) of Karachi city were compared with plants growing at the control site (Karachi University Campus). Statistical tests revealed significant ($p<0.05$) differences in chlorophyll "a", chlorophyll "b" and total chlorophyll "a+b" for *A. indica*, *C. erectus*, *G. officinale* and *Eucalyptus* sp. between all the polluted sites (Airport, Malir Halt, Quaidabad) as compared to the control site (Figs. 1-4). The highest chlorophyll content in leaves samples of all species were found from the sample collected from Karachi University (control), a site which is least affected by automobile activities (Figs. 5-7).

Azadirachta indica L.

The level of chlorophyll "a" in the leaves of *A. indica* at polluted sites of Malir Halt, Air Port and Quaidabad was recorded as 0.263, 0.201, 0.140 mg/g as compared to control 0.281 mg/g (Fig. 1). A high

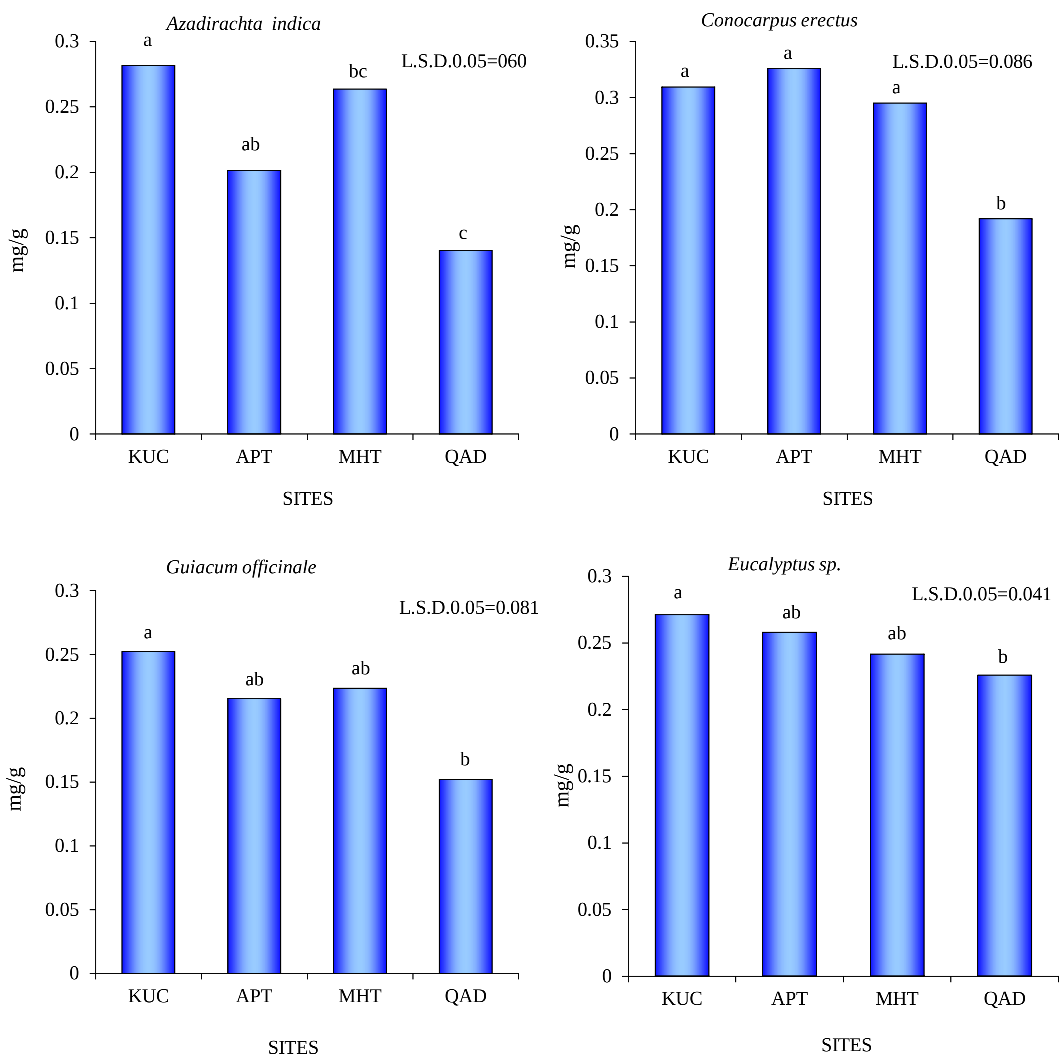

Fig. 1: Effect of automobile pollution on chlorophyll "a" (mg/g) of four tree species growing in different sites of the city
The values followed by the same letters are not significantly different (p<0.05) according to Duncan's Multiple Range Test.
Symbol used: KUC: Karachi University Campus: APT: Airport: MHT: Malir Halt: QAD: Quaidabad.

concentration of chlorophyll "b" 0.225 mg/g was found in the leaf samples of *A. indica* collected from Airport sites as compared to the control site (0.220 mg/g) followed by Mlir Halt (0.190 mg/g) and Quaidabad (0.172 mg/g) (Fig. 2). The total chlorophyll "a+b" concentration in leaf sample of *A. indica* was found high at the control site as compared to polluted sites of the city. The level of total chlorophyll "a+b" in leaf sample of *A. indica* was found in the range of 0.312-0.502 mg/g. A high (0.502 mg/g) level of total chlorophyll "a+b" was found in leaf sample of *A. indica* collected from control. Low level (0.453 mg/g) of total chlorophyll "a+b" was found in leaf sample of *A. indica* collected from Malir Halt as compared to the control site. Significantly, the lowest (0.312 mg/g) concentration of total chlorophyll "a+b" was recorded in leaf sample of *A. indica* collected from Quaidabad site as compared to control (0.591 mg/g) site (Fig. 3).

Conocarpus erectus L.

No significant effect was found in the level of chlorophyll "a" in leaf sample of *C. erectus* among the polluted site Airport, Malir Halt and control. The level of chlorophyll "a" in the leaves of *C. erectus* at polluted site (Airport) was recorded high (0.326 mg/g) as compared to control (0.309 mg/g) (Fig. 1). The

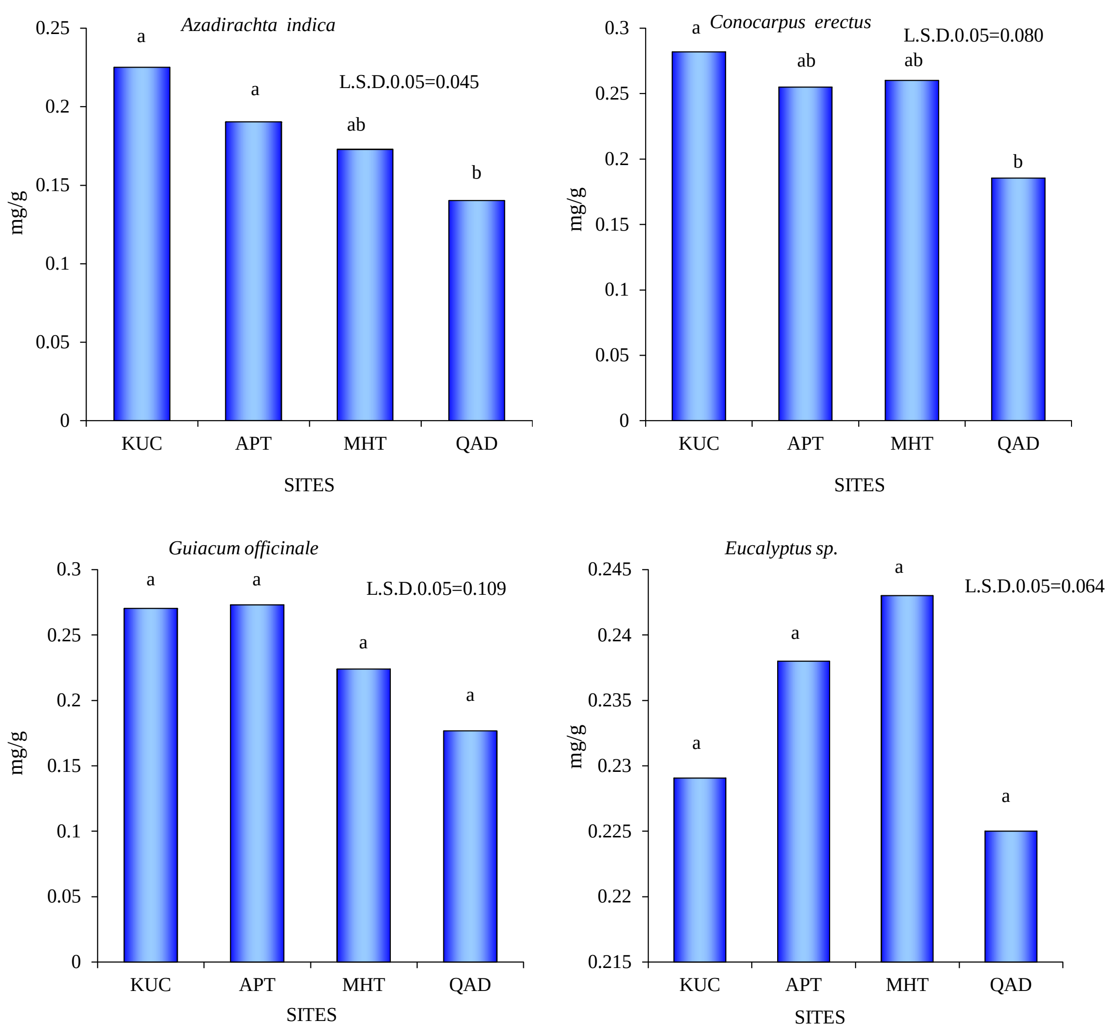

Fig. 2: Effect of automobile pollution on chlorophyll "b" (mg/g) of four tree species growing in different sites of the city
The values followed by the same letters are not significantly different (p<0.05) according to Duncan's Multiple Range Test.
Symbol used: KUC: Karachi University Campus: APT: Airport: MHT: Malir Halt: QAD: Quaidabad.

low level (0.295 mg/g) of chlorophyll "a" was recorded in the leaves of *C. erectus* collected from the polluted site of Malir Halt as compared to Airport and the control site. The significantly (p<0.05) lowest (0.191 mg/g) concentration of chlorophyll "a" was recorded in leaf sample of *C. erectus* as compared to control (0.309 mg/g) (Fig. 1). A high concentration of chlorophyll "b" (0.260 mg/g) was found in the leaf samples of *C. erectus* collected from Malir Halt site as compared to control site (0.281) followed by Air Port (0.258 mg/g) and significantly (p<0.05) the lowest 0.185 mg/g at Quaidabad (Fig. 2). A high (0.581 mg/g) concentration of total chlorophyll "a+b" was found in leaf sample of *C. erectus* collected from the Air port as compared to control (0.591 mg/g) site. Low concentration (0.555 mg/g) of total chlorophyll "a+b" was found in leaf sample of *C. erectus* collected from Malir Halt as compared to control site. Significantly the lowest (0.377 mg/g) concentration of total chlorophyll "a+b" was recorded in leaf sample of *C. erectus* collected from Quaidabad site as compared to control 0.591 mg/g) site (Fig. 3).

Guiacum officinale L.

The level of chlorophyll "a" in leaf sample of *G. officinale* was found in the range of 0.328-0.522 mg/g.

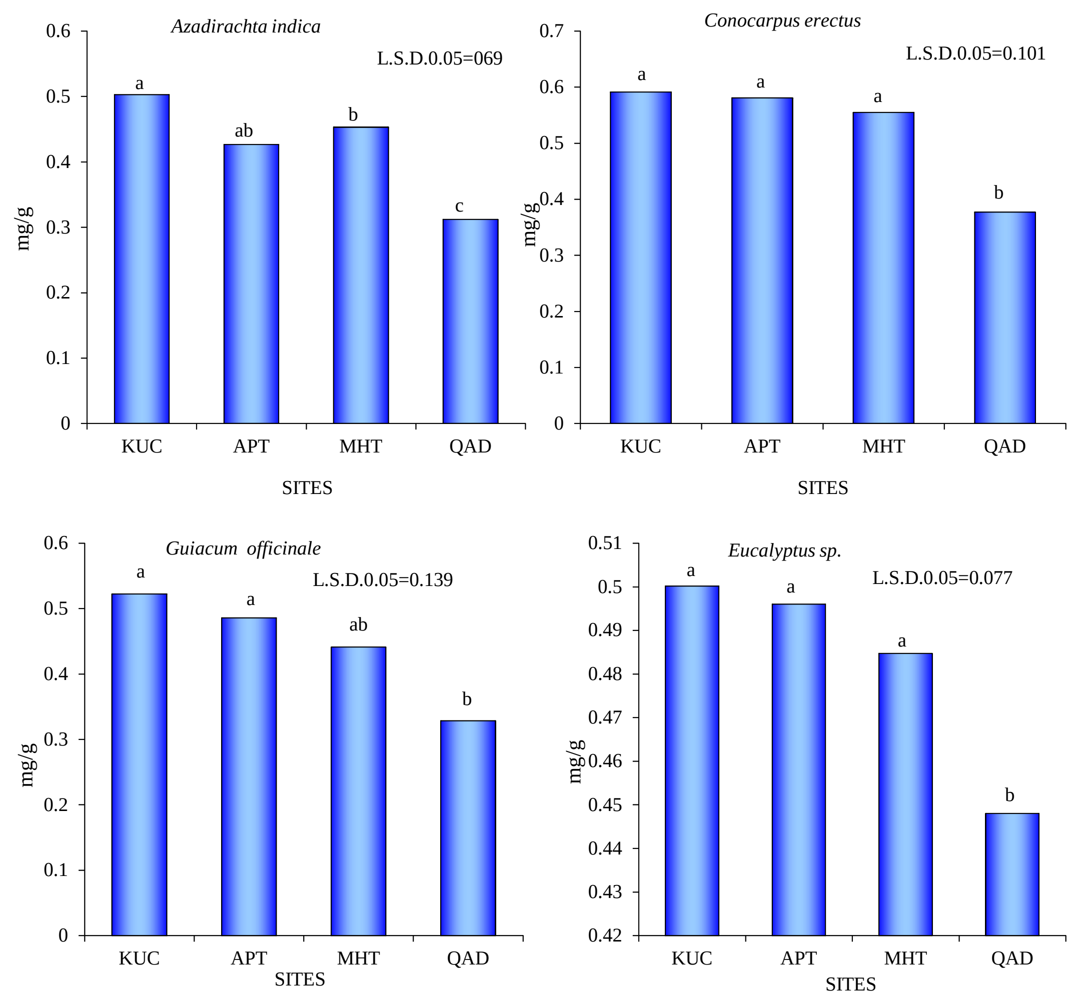

Fig. 3: Effect of automobile pollution on total chlorophyll "a+b" (mg/g) of four tree species growing in different sites of the city

Different letters indicate significant differences between sites (*P*<0.05) according to Duncan's Multiple Range Test.

Symbol used: KUC: Karachi University Campus: APT: Airport: MHT: Malir Halt: QAD: Quaidabad.

There was no significant effect of automobile pollution on chlorophyll "a" in leaf sample of *G. officinale* collected from polluted site. The concentration of chlorophyll "a" in the leaves of *G. officinale* at polluted site, Airport was recorded high (0.485 mg/g) as compared to control (0.522 mg/g) (Fig. 1). The high level (0.441 mg/g) of chlorophyll "a" was recorded in the leaves of *G. officinale* collected from the polluted site of Malir Halt as compared to Airport (0.485 mg/g) and control site (0.522 mg/g). The low (0.328 mg/g) level of chlorophyll "a" was recorded in leaf sample of *G. officinale* collected from Quaidabad as compared to control 0.309 mg/g. A high level of chlorophyll "b" (0.270 mg/g) was found in the leaf samples of *G. officinale* collected from Air Port site. Low level (0.224 mg/g) of chlorophyll "b" was found at Malir Halt and the lowest (0.176 mg/g) was recorded at Quaidabad in leaf sample of *G. officinale* (Fig. 2). The level of total chlorophyll "a+b" in leaf sample of *G. officinale* was found in the range of 0.328-0.522 mg/g (Fig. 3). A high (0.485 mg/g) level of total chlorophyll "a+b" was found in leaf sample of *G. officinale* collected from the Air port as compared to control (0.522 mg/g) site. Low concentration (0.441 mg/g) of total chlorophyll "a+b" was found in leaf sample of *G. officinale* collected from Malir Halt as compared to control site. Significantly ($p<0.05$) the lowest (0.328 mg/g) concentration of total chlorophyll "a+b" was recorded in leaf sample of *G. officinale* collected from Quaidabad site as compared to control 0.522 mg/g) site (Fig. 3).

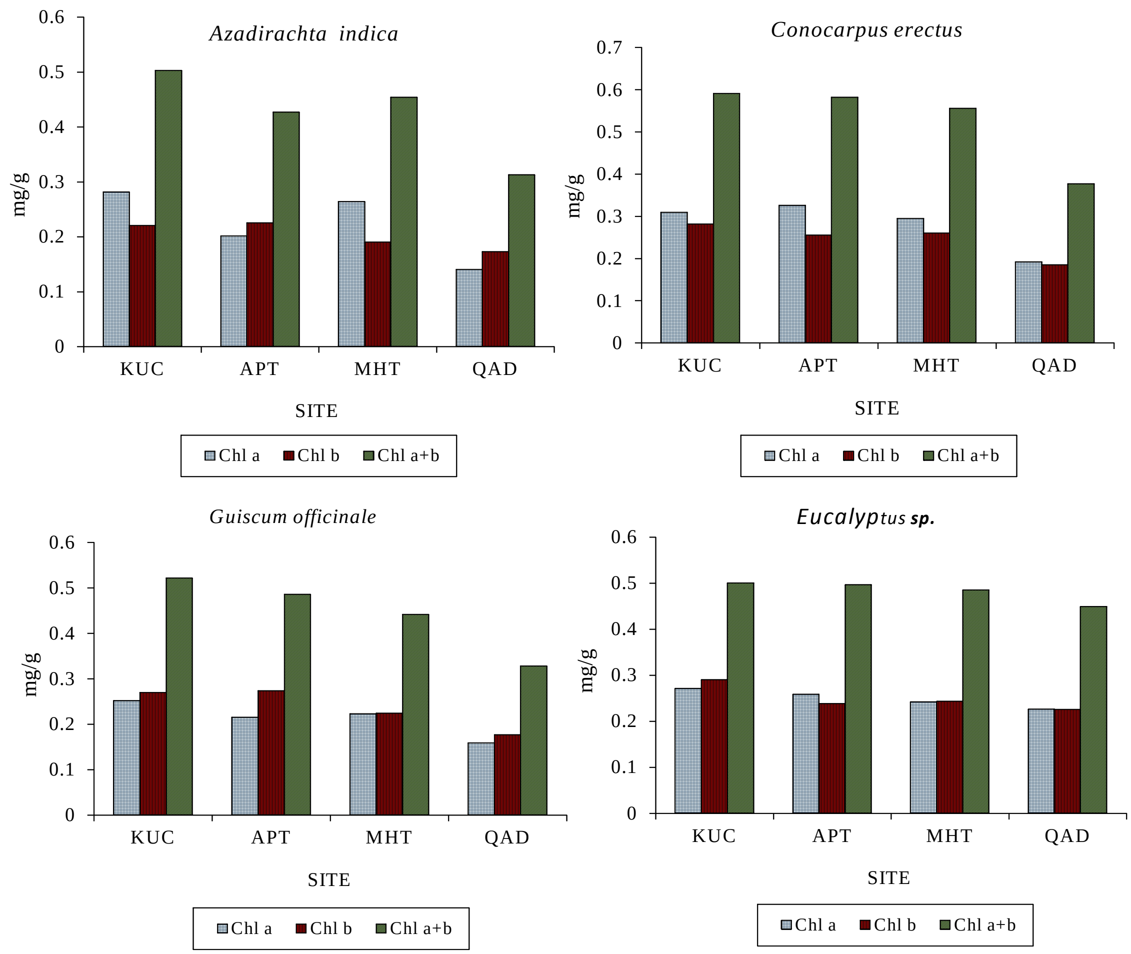

Fig. 4: Effect of automobile pollution on chlorophyll "a" chlorophyll "b" and total Chlorophyll "a+b" (mg/g) of four tree species growing at different sites of the city
Symbol used: KUC: Karachi University Campus: APT: Airport: MHT: Malir Halt: QAD: Quaidabad

Eucalyptus sp.

No significant effect of automobile pollution on the level of chlorophyll "a" in leaf sample of *Eucalyptus* sp. among the polluted sites of Airport and Malir Halt as compared to the control site was recorded (Fig. 1). The concentration of chlorophyll "a" in the leaves of *Eucalyptus* sp. at polluted site of Airport was recorded (0.258 mg/g) low as compared to control (0.271 mg/g). The better level (0.295 mg/g) of chlorophyll "a" was recorded in the leaves of *Eucalyptus* sp. collected from the polluted site of Malir Halt as compared to control site. Lowest (0.225 mg/g) level of chlorophyll "a" was recorded in leaf sample of *Eucalyptus* sp. collected from Quaidabad site as compared to control (0.271 mg/g) (Fig. 1). Similarly, high level of chlorophyll "b" (0.243 mg/g) was found in leaf samples of *Eucalyptus* sp. collected from Malir Halt site as compared to control site (0.229 mg/g) followed by Air Port (0.238 mg/g) and significantly ($p<0.05$) the lowest 0.225 mg/g was found at Quaidabad (Fig. 2). The concentration of total chlorophyll "a+b" in the leaf sample of *Eucalyptus* sp. was found in the range

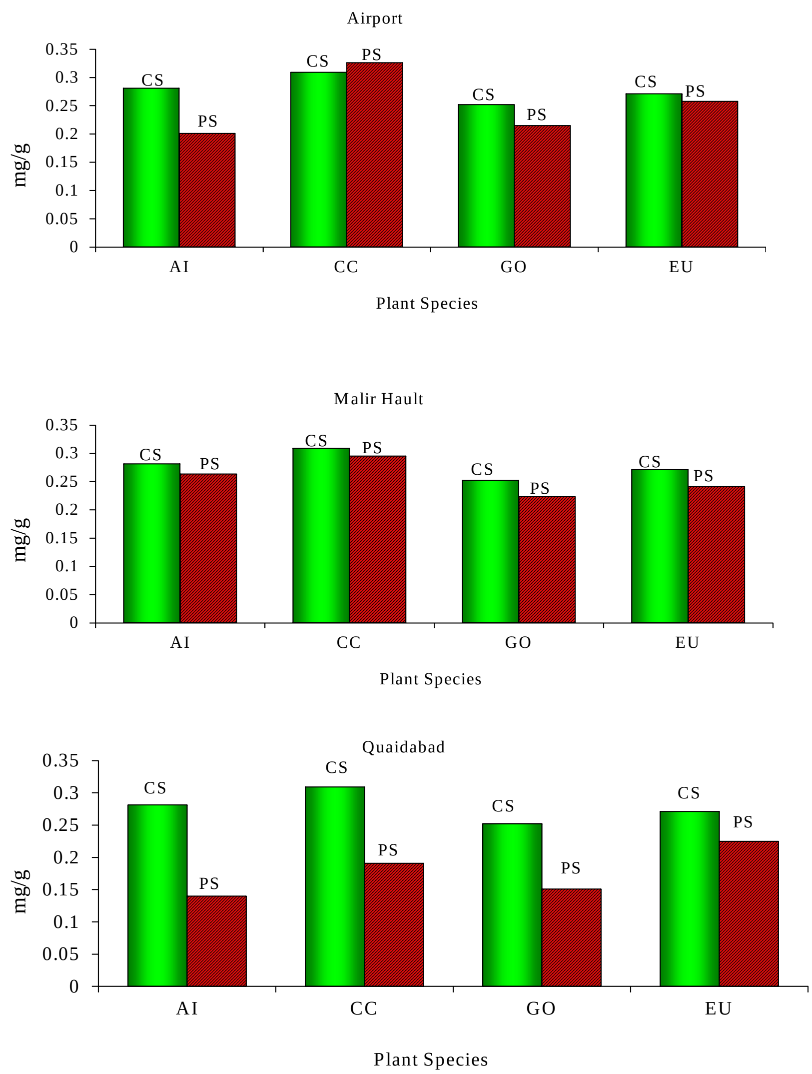

Fig. 5: Effect of automobile pollution on chlorophyll "a" content (mg/g) of four tree species growing in Airport area, Malir Halt and Quaidabad
AI= *Azadirachta indica*; CC= *Conocorpus erectus*; GO= *Guiacum officinale*; EU= *Eucalyptus* sp. CS= control site; PS= polluted site

of 0.448-0.500 mg/g (Fig. 3). A high (0.496 mg/g) concentration of total chlorophyll “a+b” was found in leaf sample of *Eucalyptus* sp. collected from Air port as compared to other polluted site of the city. The lower concentration (0.484 mg/g) of total chlorophyll “a+b” was found in leaf sample of *Eucalyptus* sp. collected from Malir Halt as compared to control site. Significantly the lowest (0.448 mg/g) concentration of total chlorophyll “a+b” was recorded in leaf sample of *Eucalyptus* sp. collected from Quaidabad site as compared to control 0.500 mg/g) site (Fig. 3).

The chlorophyll “a” level range (0.191 - 0.326 mg/g) was recorded in leaf sample of *C. erectus* followed by *A. indica* (0.140 - 0.281 mg/g), *Eucalyptus* sp. (0.225 - 0.271 mg/g) and *G. officinale* (0.151 - 0.251 mg/g). The range of chlorophyll “b” level (0.185 - 0.281 mg/g) was found in leaf of *C. erectus* as compared to in leaf of *G. officinale* (0.176 - 0.273 mg/g), *Eucalyptus* sp. (0.225-0.243 mg/g) and *A. indica* (0.172-0.225 mg/g). *C. erectus* has a range

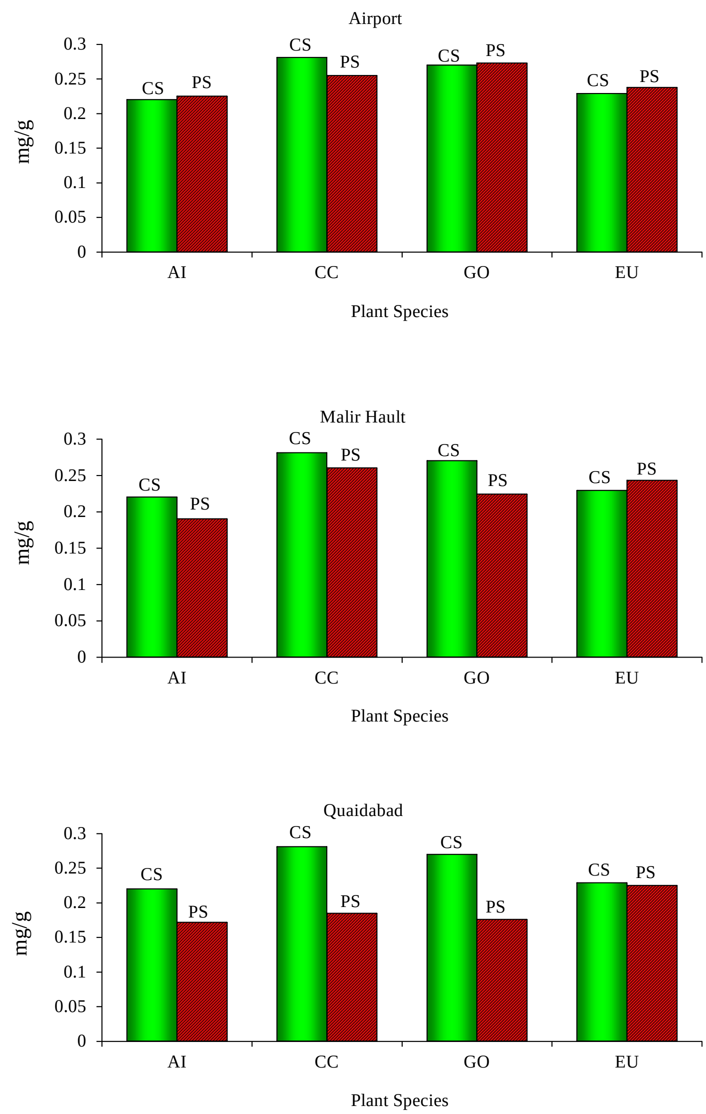

Fig. 6: Effects of automobile pollution on chlorophyll “b” content (mg/g) of four tree species growing at Airport area, Malir Halt and Quaidabad

AI= *Azadirachta indica*; CC= *Conocorpus erectus*; GO= *Guiacum officinale*; EU= *Eucalyptus* sp. CS= control site; PS= polluted site

of chlorophyll "a+b" level (0.377 - 0.591 mg/g) followed by *G. officinale* (0.325 - 0.522 mg/g), *Eucalyptus* sp. (0.312-0.502 mg/g) and *A. indica* (0.448-0.500 mg/g) (Tables 1-2). High percentage of reduction in photosynthetic pigments (chlorophyll "a", chlorophyll "b" and total chlorophyll "a+b") were recorded in the leaves of road side trees due to vehicular emissions as compared to control site (Table 2). The highest percentage of reduction in chlorophyll "a", "'b" and total chlorophyll "a+b" was recorded in the leaf samples of all tree species collected from Quaidabad site when compared with samples from control areas. The highest reduction in total chlorophyll concentration was observed in *A. indica* (37.76 %) leaf sample collected from Quaidabad site as compared to control area. The lowest percentage of reduction (9.68 %) in leaf sample of *A. indica* was recorded in sample collected from Malir Halt site. Similarly in case of *C. erectus* the highest reduction (36.16 %) was in leaf sample collected from Quaidabad site and the lowest (1.55 %) in from Airport site. Similar pattern of highest (37.10%) and lowest (13.37 %) percentage of reduction

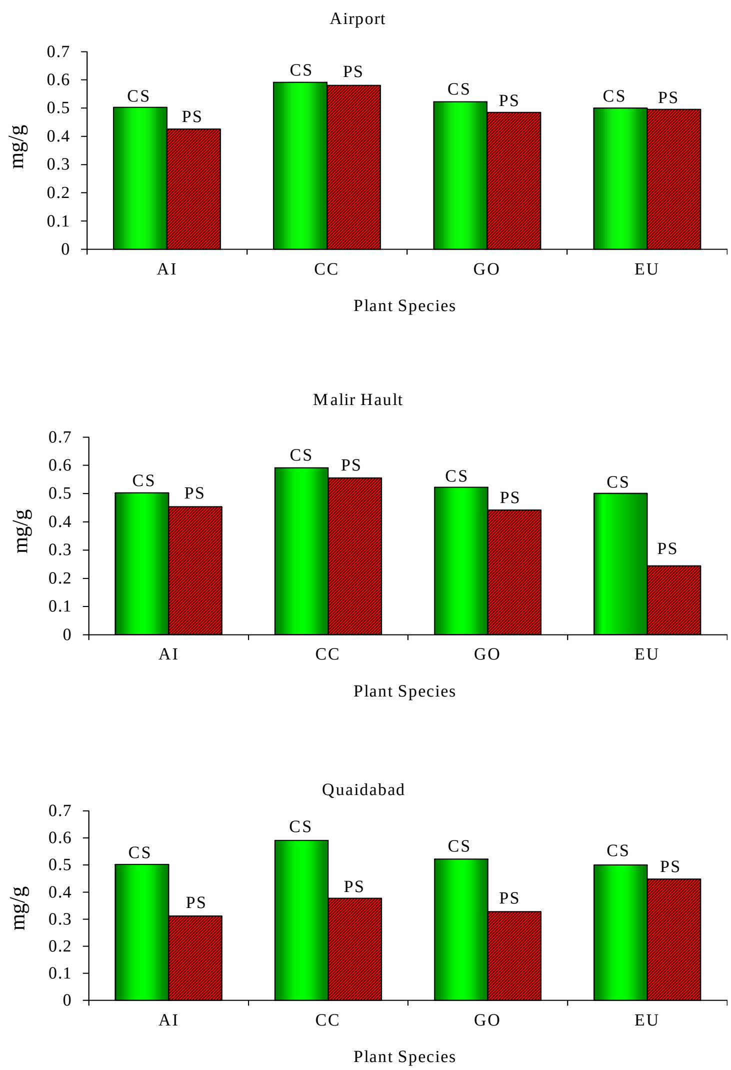

Fig. 7: Effect of automobile pollution on total chlorophyll "a+b" content (mg/g) of four tree species growing at Airport area, Malir Halt and Quaidabad
AI= *Azadirachta indica*; CC= *Conocorpus erectus*; GO= *Guiacum officinale*; EU= *Eucalyptus* sp. CS= control site; PS= polluted site

in total chlorophyll content were recorded in leaf sample of *G. officinale* at Quaidabad and Airport site leaf samples, respectively. There were no significant percentage of reduction in total chlorophyll concentration in leaf sample of *Eucalyptus* was observed at all polluted site. The lowest (0.81 %) percentage reduction of total chlorophyll content in leaf sample of *Eucalyptus* was recorded in leaf sample collected from airport site, whereas, the highest (9.36%) percentage of reduction in total chlorophyll concentration was recorded in leaf sample collected from Quaidabad site.

Chlorophyll plays an important role in plant growth. Variation in chlorophyll content has been used in many studies in order to investigate the effects of pollutants on plants. The four tree species selected (*A. indica, C. erectus, G.officinale* and *Eucalyptus* sp.) are economically important and are used for timber and roadside avenues. In the present study, the effect of automobile pollution on chlorophyll level of some tree species growing at polluted site of the city was recorded. Mean chlorophyll "a" value ranged from 0.140 to 0.326 mg/g, chlorophyll "b" from 0.172 to 0.281 directly exposed to the atmosphere, and the diversity in the leaf traits were observed among different plant species and /or locations may be interpreted as a response to the prevailing atmospheric conditions (Escudero *et al.,* 2013).

A quite lower concentration of chlorophyll contents (chlorophyll "a", chlorophyll "b" and total chlorophyll "a+b" was recorded in leave sample of plant species (*A. indica, G. officinale, C. erectus* and *Eucalyptus* sp.) collected from Malir Halt. The concentration of chlorophyll "a", chlorophyll "b" and total chlorophyll "a+b" was found lowest in leaf samples of all tree species collected from Quidabad site as compared to Malir Halt, Airport and Karachi University Campus sites. The combustion of petroleum products as a source of energy in automobile generates a variety of gases and particulates which contaminate the ambient air. The lowest concentration of chlorophyll at Quidabad site leaf sample might be due to automobile pollutants for plants growing at this site. The chlorophyll "a" and total chlorophyll "a+b" concentration significantly $p<0.05$ decreased, while no significant decrease in chlorophyll "b" was observed in leaf sample of *G. officinale* collected from all polluted sites of the city. The decrease in chlorophyll content is associated with the introduction of automobile pollutant in the environment. Different concentration of SO_2 + NO_2 mixture showed significant ($p<0.05$) changes in the chlorophyll content of *Glycine max* leaves (Hamid and Jawad, 2009). The chlorophyll is one of the most abundant organic molecules on earth (Reinbothe *et al.,* 2010). The chlorophyll performances of studied species were under the stress due to environment related pollution problems (Leghari *et al.,* 2013). In industrialized cities like Karachi, where the traffic density is rapidly increasing day by day, automobile emission is a major source of atmospheric pollution (Shafiq and Iqbal, 2012). The roadside trees in the city were under the pressure of vehicular traffic infrastructure. The pollutants emitted from the exhaust detrimentally influence the growth performance of plant species growing close to the busy roads of the city.

The deposition of lead and soot particles on the surface of leaves causes clogging of stomata and this clogging ultimately leads to reduction in photosynthetic rate which, in turn, causes a reduction in the contents of sugar, chlorophyll and protein (Joshi and Swami, 2007; Narwaria and Kush, 2012; Prajapati and Tripathi, 2008). The higher traffic exposures decreased the chlorophyll content in leaves due to automobile pollution stress. The chlorophyll "a" concentration was found more sensitive than chlorophyll "b" for *A. indica*. These studies are in agreement of Joshi and Swami (2009) who concluded

Table 1: Effect of automobile pollution on chlorophyll content mg/g of four tree species growing at different sites of city

Plant species	*Chlorophyll concentration range mg/g		
	Chl a	Chl b	Chl a+b
Azadirachta indica	0.2815* – 0.1401	0.2253 – 0.1727	0.5026 – 0.3128
Conocarpus erectus	0.3261 – 0.1918	0.2818 – 0.1854	0.5911 – 0.3773
Guiacum officinale	0.2518 – 0.1519	0.2738 – 0.1766	0.5223 – 0.3285
Eucalyptus	0.2710 – 0.2257	0.2432 – 0.2251	0.5001 – 0.4486

that vehicular induced air pollution reduces the concentration of photosynthetic pigments in trees exposed to road side pollution. A significant decrease in photosynthetic rate, stomatal conductance, intercellular CO_2 concentration, photosynthetic pigments and photosynthetic area of *Croton bonplandianum* reported and concluded that these pigments including chlorophyll "a", chlorophyll "b", total chlorophyll and carotenoids were severely affected in the stressed polluted environment and showed a significant reduction in the polluted sample with percent variation having 89, 74, 83 and 20%, respectively (Saquib *et al.,* 2010). The heavy metals in higher concentrations concerned the physiological behavior of plants and degrade the activities of photosynthetic enzymes and block the electron transport chain which reduced the chlorophyll contents (Thapar *et al.,* 2008). Lead is a toxic element discharged in the environment due to automobile activities. Lead at 50 mg $^{-L}$ concentration inhibited photosynthetic and transpiration rates and stomatal conductance of two mung beans (*Vigna radiata*) cultivars (Mung-1 and Mung-6) and concluded that the photosynthetic inhibition is due to stomatal limitations with a considerable reduction in chlorophyll "b" content of mung bean (Ahmad *et al.,* 2008). The level of chlorophyll "a", chlorophyll "b" and total chlorophyll were significantly decreased in samples collected from the polluted environment nd agreed with the findings of other researchers. The pollutants inhibited the photosynthetic activity of plants growing in such environment which resulted in depletion of chlorophyll and carotenoid contents of leaves (Chauhan and Joshi, 2008). The leaves of plants absorb these pollutants from the atmosphere and could cause a reduction in chlorophyll contents (Miszalski and Mydlarz, 1990).

The findings may be helpful for civic agencies working for nature conservation and management of roadsides sites. It was concluded that autovechicular exhaust emission significantly $p<0.05$ affected the level of chlorophyll pigment, chlorophyll "a", chlorophyll "b" and total chlorophyll "a+b" for all tree species at polluted sites. Information is available on the effect of air pollu- tion on biochemical characteristics of plant species growing in the polluted environment. The highest chlorophyll content in leaves samples of all species were found from sample collected from Karachi University, a site which is least affected by automobile activities. Every species showed a variation in chlorophyll concentrations with significant ($p<0.05$) differences between locations. The chemical responses of leaf sample of *Ligustrum lucidum* taken from different sites in the city of Córdoba, Argentina for the determination of chlorophyll studies showed sensitivity to traffic pollution exposure (Carreras *et al.,* 1996).

CONCLUSION

The effect of automobile pollution on chlorophyll content (chlorophyll "a", chlorophyll "b", chlorophyll "a+b") for different tree species (*A. indica, C. erectus, G. officinale* and *Eucalyptus* sp.) growing at different polluted sites (Airport, Malir Halt, Quaidabad) of the city as compared to the control site (Karachi University Campus) was determined. All the species showed a decrease in chlorophyll content as compared to sample collected from the control site. The highest effects were recorded in the leaf sample collected from the Quaidabad site. It was concluded that autovechicular exhaust emission significantly affected ($p<0.05$) the concentrations of chlorophyll "a", chlorophyll "b" and total chlorophyll "a+b" in the following order of sequence for all tree species among the sites as Quaidabad>Malir Halt>Airport>University Campus.

Table 2: Percentage reduction in chlorophyll contents (mg/g) of four tree species growing at different roads as compared to control

SITE	Chlorophyll contents								
	Chlorophyll "a"			Chlorophyll "b"			Total chlorophyll "a+b"		
	APT	MHT	QAD	APT	MHT	QAD	APT	MHT	QAD
Azadirachta indica	28.49	6.35	50.23	+2.22	13.28	21.54	15.12	9.68	37.76
Conocarpus erectus	+5.43	4.59	37.98	9.22	7.50	34.20	1.55	5.98	36.16
Guiacum officinale	14.59	11.38	39.74	+1.36	17.06	34.61	13.37	15.41	37.10
Eucalyptus sp.	4.79	10.88	16.97	+3.91	+6.20	1.74	0.81	2.79	9.36

Symbol used: SITE = APT = Airport, MHT = Malir Halt, QAD= Quaidabad
\+ = Percent increase

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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