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A Case Study :

Air pollution tolerance index of tree sepcies growing in traffic area of Madurai, Tamil Nadu

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ABSTRACT

Air pollutant from vehicles affect tree by injuring and killing them, and by adversely affecting physiological processes so as to decrease growth without necessarily causing visible symptoms of injury. In the present study, the four leaf parameters such as pH, relative water content, total chlorophyll and ascorbic acid for the five tree species such as *Peltophorum ferrugineum*, *Pongamia glabra*, *Polyalthia longifolia*, *Tectona grandis* and *Ailanthus excelsa* in three different sampling stations such as residential area, commercial cum heavy traffic area and less traffic area has been monitored. The air pollution tolerance index (APTI) has been evaluated, incorporating the biochemical parameters to categorize the plants as sensitive or resistant to air pollutants. The analysis of the parameters show that all the four parameters are high in the residential area compared to the sampling stations exposed to automobile exhaust. It reveals that the air pollutants from the vehicles enter the plants through the natural opening usually stomata and react within leaf tissues. They do not cause tissue death but inhibit leaf function.

Key words : Ascorbic acid, Chlorophyll content, Air pollution tolerance index, Biochemical parameter

In the recent years, the concern about environmental pollution has grown appreciably. It has come to be recognized as one of the major threats to the existence of human and various other species of our planet. Air pollution deteriorated the ecological condition and would be defined as the fluctuation in any atmospheric constituent from the value that would have existed without human activity. It is really concerned because the accumulation of pollutants is more in the areas where there is higher concentration of people and traffic congestion. Emissions from heavily loaded and badly maintained automobiles, domestic and industrial combustion of coal and other industrial emission account for most of the urban pollution in India.

Mainly automobile exhaust contribute significantly about 80 per cent carbon monoxide emission. Its concentration vary depending upon the density of vehicular traffic. Its level is much below the threshold concentration in areas where traffic is less. It has detrimental effects on plants, when exposed for a long time. It affects leaf drop, leaf curling, reduction in leaf size and chlorophyll. Automobile exhausts emit maximum hydrocarbons in the atmosphere. In India, automobiles are the chief source of hydrocarbon. About 40 per cent of the vehicular exhaust hydrocarbons are unburnt fuel components. It has adverse effects on vegetation. It inhibit plant growth and damage leaf tissues and death of flowering plants.

Madurai city is the trade and commercial center of south region of Tamil Nadu. The current population of the city stands at 11 lakh. Urban Madurai is a depositary for most of the pollutants in the air. This study is intended to biomonitor five tree species such as *Peltophorum ferrugenium*, *Pongamia glabra*, *Polyalthia longifolia*, *Tectona grandis* and *Ailanthus excelsa* at various sites along the roadside of city exposed to vehicular emissions.

MATERIALS AND METHODS

Selection of sampling stations:

Historically as well as mythologically, Madurai is perhaps the oldest city in Tamil Nadu. Madurai is the second largest city in Tamil Nadu state. It has three national Highways namely NH-7, NH-45B, NH-49 and state highways passing through it (Fig. 1). During summer, the temperature varies from a maximum of 39.1^{0}C to a minimum of 25.0^{0}C and during winter, the temperature changes from a maximum 29.0^{0}C to a minimum 20.0^{0}C. The city is emerged as an important center of textiles and engineering industries. It is also fast growing center for tourism, having high traffic column.

The sampling stations are selected keeping in view of the importance of the zone and the nature of activity. A total of three sampling stations consisting of residential, commercial and traffic intersections are chosen for the present study. Avaniyapuram is a purely residential area and a very much traffic free zone of urban city. Integrated Bus stand (Roadside sampling site 1) is at a busy traffic

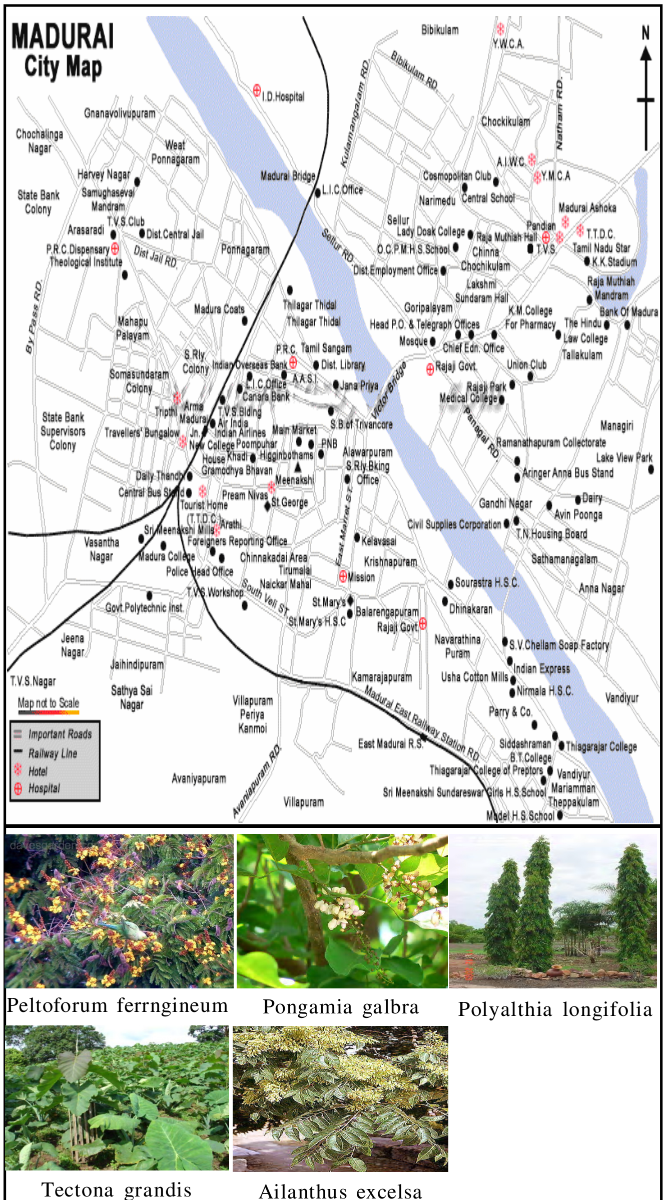

Fig. 1 : Madurai city map

point with density of commercial area and Arignar Anna Bus Stand is a less traffic area (Roadside sampling site 2).

Collection of leaf sample:

In the present study, the leaf samples of the three different sampling stations such as Avaniyapuram, Integrated bus stand and Aignar Anna bus stand and five different tree species namely *Ailanthus excelsa, Peltophorum ferrugineum, Polyalthia longifolia, Pongamia glabra* and *Tectona grandis* were collected.

Plants were investigated with respect to total chlorophyll, ascorbic acid, relative water content and leaf extract pH. Fully expanded leaves, devoid of any leaf injury symptoms, were collected between 8.00 and 9.00 a.m. For trees, five individuals were identified along the pollution sources and at the control site, selected randomly in a belt transect measuring 50x75m, and foliar samples in triplicate were taken from each of them.

Biomonitoring:

The collected leaf samples (0.5 gm) was crushed and homogenized in 50 ml deionised water and the pH of the suspension was measured with a photovoltaic pH meter, using a glass electrode. The per cent of relative water content was calculated by using the initial and final weight of leaf material (Falla *et al.*, 2000). Total chlorophyll (mg g^{-1} dry weight) was estimated following the method of Mac Lachlan and Zalik (1963). The ascorbic acid content (mg g^{-1} dry weight) was determined using the modified colorimetric 2,6-dichlorophenol-indophenol method described by Keller and Schwager (1977).

Statistical analysis:

Results were statistically analyzed using two-way analysis of variance (ANOVA) (Armitage and Berry, 1994). Multicomparison of analysis of variance at 99% confidence interval was carried out for all the plant species on all characteristics.

Evaluation of Air pollution Tolerance index:

Monitoring of the tree species was done at three sampling stations. During present investigation, ascorbic acid content, leaf extract pH, total chlorophyll content and relative water content was taken together in the form of mathematical expression to obtain an empirical value, signifying the Air Pollution Tolerance Index (APTI) (Raza *et al.*, 1985).

$$\text{APTI} = \frac{\text{A (T + P)} \mid \text{R}}{10}$$

where,

A = Ascorbic acid content (mg g^{-1} fresh weight)
P = Leaf extract pH
T = Total chlorophyll (mg g^{-1} dry weight)
R = Per cent relative water content of leaf.

Plants had been classified according to their degree of sensitivity and tolerance towards various air pollutants, as given in Table 1. Sensitive species were more useful as bioindicators and tolerant species were more appropriate as accumulative indicators.

Air pollution index (APTI) is used to examine the susceptibility of a number of plant species growing in the urban city of Madurai.

Table 1 : Tolerance index of air pollution (APTI)	
Index value	Remarks
1-10	Sensitive
10-16	Intermediate
More than 17	Tolerant

RESULTS AND DISCUSSION

Plant response to air pollution can be used to assess the quality of air that may provide early warning signals of air pollution trend. The variations in pH value of leaf extract, relative water content, total chlorophyll content and ascorbic acid were used as parameters for monitoring air pollution impact on plant metabolism, for all the five selected species at different sampling sites. All the biochemical indicators exhibited significant variation (r< 0.001) from species to species and station to station (Table 2, 3, 4 and 5).

Peltophorum ferrugineum:

At the residential area, *Peltophorum ferrugineum* exhibited 6.80 of leaf extract pH. There is significant reduction of 7.35% and 5.88% at the roadside sampling sites 1 and 2, respectively. Relative water content of the plant species at the residential area is 72.19%. It is reduced to 5.97% and 4.57% at the roadside sampling sites 1 and 2. At the roadside sampling site 1, the total chlorophyll content was reduced to 6.98% and the

Table 2 : Leaf extract pH of the selected plant species along roadside in study area

Sr. No.	Sampling location	*Peltophorum ferrugenium*		*Pongamia glabra*		*Polyalthia longifolia*		*Tectona grandis*		*Ailanthus excelsa*	
		pH	%R	pH	%R	pH	%R	pH	%R	pH	%R
1.	Residential area	6.80		6.68		6.25		6.30		6.35	
2.	Roadside sampling site site 1	6.30	7.35	6.05	9.02	5.70	8.80	5.55	11.90	5.55	12.60
3.	Roadside sampling site 2	6.40	5.88	6.20	6.77	6.10	2.40	6.00	4.76	6.25	1.57

Where %R = Percentage reduction. Overall difference is based on two-way ANOVA. Test was performed for comparison of pH of all the plant species at their respective locations, where F values in ANOVA are significant. Significant difference at $\rho < 0.001$ by multiple comparison tests.

Table 3 : Relative water content (RWC) of the selected plant species along roadside in study area

Sr. No.	Sampling location	*Peltophorum ferrugenium*		*Pongamia glabra*		*Polyalthia longifolia*		*Tectona grandis*		*Ailanthus excelsa*	
		RWC	%R	RWC	%R	RWC	%R	RWC	%R	RWC	%R
1.	Residential area	72.19		69.40		71.11		65.23		70.76	
2.	Roadside sampling site site 1	67.88	5.97	61.42	11.50	64.62	9.13	59.69	8.49	65.25	7.79
3.	Roadside sampling site 2	68.89	4.57	65.86	5.10	69.57	2.17	63.67	2.39	67.58	4.49

Where %R = Percentage reduction. Overall difference is based on two-way ANOVA. Test was performed for comparison of pH of all the plant species at their respective locations, where F values in ANOVA are significant. Significant difference at $\rho < 0.001$ by multiple comparison tests

Table 4 : Total chlolophyll (TC) (mg/gm) of the selected plant species along roadside in study area

Sr. No.	Sampling location	*Peltophorum ferrugenium*		*Pongamia glabra*		*Polyalthia longifolia*		*Tectona grandis*		*Ailanthus excelsa*	
		TC	%R	TC	%R	TC	%R	TC	%R	TC	%R
1.	Residential area	2.15		1.88		1.29		1.38		1.23	
2.	Roadside sampling site 1	2.00	6.98	1.69	10.11	1.09	15.50	1.14	17.39	1.01	17.89
3.	Roadside sampling site 2	2.01	6.51	1.76	6.38	1.28	0.78	1.26	8.70	1.20	2.44

Where %R = Percentage reduction. Overall difference is based on two-way ANOVA. Test was performed for comparison of pH of all the plant species at their respective locations, where F values in ANOVA are significant. Significant difference at $\rho < 0.001$ by multiple comparison tests

Table 5 : Ascorbic acid (AA) (mg/gm) of the selected plant species along roadside in study area

Sr. No.	Sampling location	Plant species									
		Peltophorum ferrugenium		*Pongamia glabra*		*Polyalthia longifolia*		*Tectona grandis*		*Ailanthus excelsa*	
		AA	%R	AA	%R	AA	%R	AA	%R	AA	%R
1.	Residential area	5.13		4.25		5.14		6.07		4.29	
2.	Roadside sampling site 1	4.98	2.92	4.07	4.24	4.83	6.03	5.21	14.17	4.02	6.29
3.	Roadside sampling site 2	5.02	2.14	4.10	3.53	4.90	4.67	5.76	5.11	3.84	10.49

Where %R = Percentage reduction. Overall difference is based on two-way ANOVA. Test was performed for comparison of pH of all the plant species at their respective locations, where F values in ANOVA are significant. Significant difference at $\rho < 0.001$ by multiple comparison tests

reduction was 6.51% at the roadside sampling site 2.There was reduction of 2.92% and 2.14% in the ascorbic acid of the leaf samples collected from the roadside sampling sites 1 and 2 compared to the residential area. For the *Peltophorum ferrugineum* species, all the four-biochemical parameters were reduced in the roadside sampling stations 1 and 2 compared to the residential area. This clearly reveals that a decrease in the biochemical parameter of *Peltophorum ferrugineum* species growing at the roadside sampling sites 1 and 2 with heavy vehicular traffic as compared to Avaniyapuram where vehicular traffic is low or nil.

Pongamia glabra:

Biochemical indicators of *Pongamia glabra* at all the bioindicator stations varied significantly. Maximum reduction of 9.02% and 6.77% in leaf extract pH was observed at the roadside sampling sites 1 and 2 compared to the residential area. The relative water content at the residential area of the plant species is 69.40%. It was reduced to 61.42% and 65.86% at the roadside sampling sites 1 and 2, respectively. Roadside sampling sites exhibited 10.11% and 6.38% reduction in the total chlorophyll content compared to the residential area. Ascorbic acid also showed decrease over control site at all the stations. 4.24% reduction was observed at roadside sampling site 1 followed by roadside sampling site 2 (3.53%). *Pongamia glabra* showed the reduction in all the four leaf parameters at the roadside sampling sites. The automobile pollution impact was realized more in the integrated bus stand (roadside sampling site 1) compared to Arignar Anna bus stand.

Polyalthia longifolia:

Leaf extract pH at the roadside sampling site 1 showed 8.80% reduction followed by 2.40% reduction at the roadside sampling site 2 as compared to residential area. Decrease in relative water content was exhibited at the roadside sampling sites 1 and 2. The decrease of 9.13% was observed at roadside sampling site 1 followed by roadside sampling site 2 (2.17%). Total chlorophyll content was found to be significantly reduced. Maximum reduction (15.50%) was revealed at roadside sampling site 1 followed by the roadside sampling site 2 (0.78%). Ascorbic acid content was significantly decreased in the roadside sampling stations and again maximum loss (6.03%) was observed at the roadside sampling site 1 followed by roadside sampling site 2 (4.67%). Significant reduction in all the four-biochemical parameters was recorded for *Polyalthia longifolia* species at the traffic area.

Tectona grandis:

The leaf extract pH of *Tectona grandis* showed a maximum reduction of 11.90% at roadside sampling site 1 and a subsequent reduction of 4.76%at sampling site 2. Maximum loss of relative water content (8.49%) was exhibited at roadside sampling site 1 followed by 2.39% at sampling site 2.Maximum reduction (17.39%) in chlorophyll content was observed at roadside sampling site 1 while at sampling site 2, loss of 8.70% was observed. At all the roadside sampling sites, there was reduction in ascorbic acid content. Maximum loss of 14.71% was encountered at sampling site 1 followed by 5.11% reduction at sampling site 2. Effect of air pollution was much pronounced in *Tectona grandis* so that there was maximum reduction in the four-biochemical parameters.

Ailanthus excelsa:

Ailanthus excelsa exhibited 12.60% and 1.57% reduction in pH at roadside sampling sites 1 and 2, respectively. Significant reduction (7.79%) in relative water content was observed at roadside sampling site 1, followed by a loss of 4.49% at roadside sampling site 2. The entire roadside sampling sites showed significant reduction in total chlorophyll content (r<0.001%). Maximum reduction (17.89%) in total chlorophyll content was exhibited at roadside sampling site 1 followed by 2.44% reduction at sampling site 2. Maximum decrease of 10.49% reduction was encountered at roadside sampling site 2 as compared to 6.29% reduction at roadside sampling site 1. The four bioindicators such as pH, relative water content, total chlorophyll and ascorbic acid showed maximum reduction at roadside sampling sites 1 and 2 (Fig. 2).

Analysis of the four bioindicators such as pH, relative water content, total chlorophyll and Ascorbic acid content in the different bioindicator stations residential area (Avaniyapuram), road side sampling site 1 and 2 for all the five species *Peltophorum ferrugineum, Pongamia glabra, Polyalthia longifolia, Tectona grandis and Ailanthus excelsa* shows that all the four parameters are more in the residential area that is the unpolluted site. But, the air pollutant cause more stress on the roadside trees, which directly affected the parameters, that is pH, relative water content, total chlorophyll and ascorbic acid. These parameters are reduced to a greater extent. The air pollutants from the vehicles enter plants through natural opening usually stomata and react within leaf tissues to inhibit photosynthesis. When the toxic gases enter the leaves, they do not cause tissue death but inhibit leaf function. This is the reason for greater reduction of chlorophyll content, ascorbic acid, relative water content

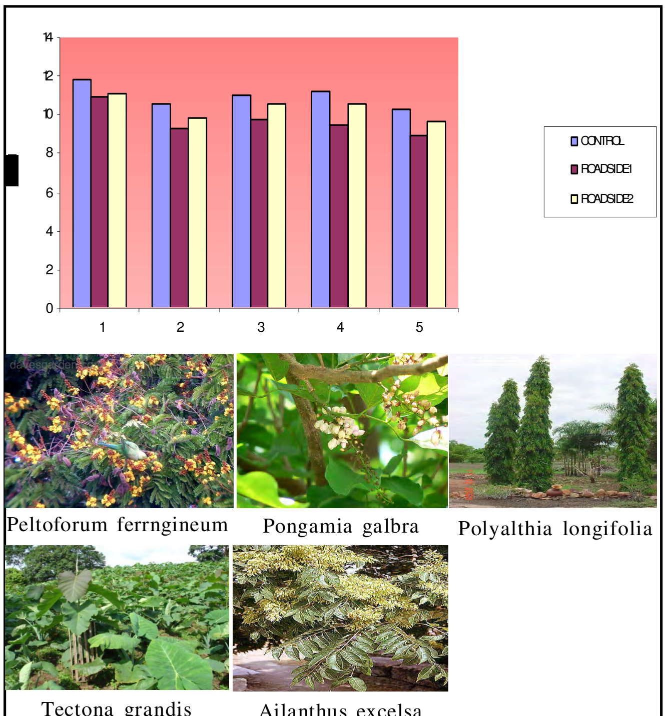

Fig. 2 : Air pollution tolerance index of the five selected species growiong in residential and traffic areas 1 and 2 Madurai

and pH in roadside sampling sites 1 and 2.

Oxides of nitrogen are the main product of combustion of nitrogen and automobile exhaust produced by the combustion of gasoline. It damages the leaves of plants, retards the photosynthetic activity. Trees exposed to 110 PPM of oxides of nitrogen cause leaf spotting and break down of plane tissues. It suppresses the growth of the plants. Sulphur dioxide is primarily as a result of Diesel fuel vehicle emission. As the number of vehicles are increased in hundred fold in Madurai city, the air pollutant (concentration of sulphur dioxide) in the atmosphere is increased more in the Integrated Bus stand (Road side sampling site 1) compared to Arignar Anna bus stand (Road side sampling site 2).

Madurai is the corporation city where commuters are primarily dependent on the single mode of transport system that is road. This has led to an enormous increase in the number of vehicles, with the associated problems of traffic congestion and increase in air pollution. As a result, among the various sources of air pollution, traffic is a major contributer of air pollution arising out of increasing number of vehicles. It is thus concluded that the pollutant from the automobile exhaust affect the plants which are on the road side. In the Integrated Bus Stand, traffic congestion, increased human activity, industries in the vicinity of the bus stand and high buildings existing parallel to each other increase the air pollutant in the atmosphere. In the Arignar Anna bus stand, the population and the number of moving vehicle are less. It makes it clear that air pollution effect is more pronounced at the road side sampling site 1 compared to site 2. All the four biochemical parameters are reduced more at the roadside sampling site 1 compared to site 2.

Although all the five species showed significant variation in all the biochemical indicators, the extent up to which plant species were affected varied from species to species and station to station. Almost all the species showed maximum variation in the roadside sampling site 1, which is found to be severe air pollution site. A considerable loss in relative water content, chlorophyll and ascorbic acid in the leaves of plants exposed at roadside sampling site 1 (severe air pollution site) supports the argument that the chloroplast is the primary site of attack by air pollution.

Air pollutants make their entrance into the tissues through the stomata and cause partial denaturation of the chloroplast and decreases chlorophyll contents in the cells of polluted leaves. Rao and Leblanc (1966) mentioned that high amount of gaseous sulphur dioxide causes destruction of chlorophyll and that might be due to the replacement of Mg^{2+} by two hydrogen atoms and

Table 6 : Air pollution tolerance index of the five selected species at different biondicator stations (Residential area, road side sampling site 1 and 2)

Name of the species	Family	Residential area	Road side 1	Road side 2
Peltphorum ferrugineum	Caesalpiniaceae	11.805	10.92	11.1
Pongamia glabra	Leguminosae	10.56	9.29	9.85
Polyalthia longifolia	Annonaceae	10.99	9.75	10.58
Tectona grandis	Verbenaceae	11.23	9.45	10.55
Ailanthus excelsa.	Simaroubaceae	10.33	8.96	9.62

degradation of chlorophyll molecules to phecophytin. Maximum depletion in chlorophyll content at sampling site 1 may be due to the maximum pollution load at this site. It is concluded that vegetation at roadside with heavy traffic and markets is much affected by vehicular emission. Significant reduction in chlorophyll content at the sampling site 1 is in accordance with N.D.Wagh *et al.* (2006) findings. The sampling site 2 and Residential area showed less depletion due to lower pollution load. *Tectona grandis* experienced the most impact of pollutant followed by *Ailanthus excelsa, Pongamia glabra, Polyalthia longifolia* and *Peltophorum ferrugineum*.

Air pollution tolerance indices of five selected species growing in three different localities of Madurai are calculated. Air pollution tolerance level of each species is different and do not show a uniform behaviour. Plants having higher APTI value are more tolerant to air pollution than those having lower APTI values.

Table 6 revealed that there is maximum reduction in the APTI value at the roadside sampling site 1 compared to site 2.For *Peltophorum ferrugineum* the APTI for the residential area is 11.81 and at the roadside sampling site 1 and 2 are 10.92 and 11.1. As the Index value is reduced from 11.80 to 10.92 and 11.1, this indicates that plant loses the intermediate tolerance and becomes sensitive towards pollution. For *Pongamia glabra* the APTI for residential is 10.56, which is reduced to 9.29 and 9.85 at the roadside sampling sites 1 and site 2. It shows that *Pongamia glabra* loses the intermediate tolerance and becomes sensitive towards pollution. For *Polyalthia longifolia*, the APTI for the residential area is 10.99, which are reduced by the air pollution to 9.75 and 10.58 at the roadside sampling site 1 and 2, respectively. This species loses the tolerance towards pollution and becomes more sensitive. For *Tectona grandis*, the APTI for the residential area is 11.23, which is decreased to 9.45 and 10.55 at the roadside sampling site 1 and 2, respectively. This species loses the tolerance towards pollution and becomes more sensitive. For *Ailanthus excelsa*, the APTI for the residential area is 10.33 it is reduced to 8.96 and 9.62 at the roadside sampling sites 1 and 2. *Ailanthus excelsa* loses the resistance towards tolerance and becomes sensitive towards pollution.

Plants species growing in polluted areas (Road side sampling sites 1 and 2) indicated that the urban air pollution causes the reduction in the leaf extract pH, relative water content, total chlorophyll and ascorbic acid in the leaves. The magnitude of reduction in all the four parameters is maximum at the zone receiving maximum pollution load. The responses of plants to pollutants produce a simple and low cost method of monitoring gaseous pollutants (Posthumus, 1985). The study showed that the urban air pollution level in Madurai is detrimental for the growth of plan.

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