Plants as Bio - indicators and Bio - monitors of Urban Air Pollution

Kiran Kumar S J, K. M. Sharu Raj, Deepalakshmi A. P

Department of PG Studies and Research in Biotechnology, Government Science College,Bangalore- 560 001

Abstract: Air pollution is one of the major problems faced by the people all over the world. This paper describes the tolerance among roadside plants to air pollution. Evaluation of air pollution tolerance index (APTI) of 5 selected wild roadside plant species along the busy roadways of Bangalore was carried out to assess their response to ambient levels of air pollutants. There was a significant reduction in total chlorophyll, ascorbic acid and relative water content showing an inverse relationship with traffic density. Similarly, pH of leaf extract showed an exponential decrease with increase in traffic density and drifted towards acidic range. *Cynodondactylon*cancan be used as an effective bio - indicator, while *Ricinuscommunis* could serve as a sink to air pollutants. The plant species with higher APTI value can be used for plantation program in urbanized and industrial areas. This helps in the reductionof the effects of air pollution, making the ambient atmosphere clean and healthy.

Key words: Air pollution tolerance index, ascorbic acid, total leaf chlorophyll, relative water content, *Cynodondactylon*, *Ricinuscommunis*

1. INTRODUCTION

Air is an essential component of the environment. Air pollution is a global problem faced by both the developed nations as well as the developing ones. Air pollution is of growing concern due to its ever increasing threats on human health. Road traffic emissions have emerged as the major cause of poor air quality. However concentrations of traditionally important pollutants such as sulphur dioxide (SO_2) and black smoke have declined substantially in the recent past due to stricter rules laid down by pollution control boards. Atmospheric air contains about 78 % nitrogen, 21 % oxygen, 0.93 % argon, 0.038 % carbon dioxide and several other trace gases, but due to human activities changes in the earth's atmosphere has become a prime concern for present world (Chauhan, 2010). It is a known fact that 60 % of air pollution in city is caused by automobiles alone (Gaikwad et al., 2004). Urban air pollution is derived largely from combustion processes and is a complex mixture containing many toxic components (Cohen et al., 2004). The major air pollutants which contribute to air pollution are carbon dioxide, carbon monoxide (CO), sulphur oxides (SO_X), nitrogen oxides (NO_X) and particulate matter. The effect of these pollutants is observed at acute level on sensitive species of plants, animals and human beings. Plants are directly affected by these pollutants via leaves or indirectly via soil acidification (Steubing et al., 1989). Most plants when exposed to air pollutants experience physiological changes before exhibiting visible damage to leaves (Dohmen et al., 1990).

Air Pollution Tolerance Index value can be used to determine the ability of a plant to encounter stress arising due to pollution. Sensitivity and tolerance to air pollution stress varies with different plant species. The impact of air pollution on plants can be evaluated by using different parameters such as relative water content, ascorbic acid content, leaf chlorophyll content, leaf pH can be used to evaluate.

2. MATERIALS AND METHODS

2.1Habitat

Located on the Deccan Plateau in the south - eastern part of Karnataka, Bangalore is India's third most populous city and fifth - most populous urban agglomeration. It is located at the heart of the Mysore Plateau with an average elevation of 900 m. It is located at 12.97° N 77.56° E and covers an area of 741 km^2.Generally the soil is red loamy to red sandy in nature and is suitable for the growth of the plant. The pH is usually on the alkaline range and poor in organic content hence low in fertility. The city experiences an agreeable climate free from extremes. Bangalore experiences a tropical savanna climate with distinct wet and dry seasons. The coolest month is December and the hottest month is April and vegetation involves large deciduouscanopy. The climatic features of the city favors the growth of herbs, shrubs and trees. The ground vegetation becomes dominant in the monsoon season. Flowering of plants are seen until the end of January. Estimation shows that Bangalore harbours 41.71 lakh vehicles, of which 28.81 lakh are two wheelers, 7.92 lakh cars, 1.62 lakh autos and 3.36 lakh other vehicles.

2.2 Experimental sites

The sites which are selected for the study includes a residential area (BTM layout), an industrial area (Peenya industrial estate), a commercial area (Rajajinagar), and a control site.

2.3Plants selected for the study

The plant species selected for the investigation include:

SPECIES	FAMILY
Cynodondactylon(L.) Pers.	Poaceac.
Ricinuscommunis(L.)	Euphorbiaceae
Tabebuiachrysantha(Jacq.) and G. Nicholson	Bignoniaceae
*Spathodeacampanulata*P.Beauv	Bignoniaceae
Delonixregia(Boj. ex Hook.) Raf.	Fabaceae

Fresh leaf samples of these plants were collected and analysed for the following parameters.

2.4Determination of pH

The pH of the sample was determined by homogenizing 5g of fresh leaves in 10 mL deionised water. This was filtered and pH of the leaf extract was measured after calibrating pH meter using the buffer solution.

2.5 Determination of total chlorophyll

Total chlorophyll was estimated by the method of Arnon, 1949. One gram fresh leaf sample was taken in a pre - chilled mortar and macerated in 80 % (v/v) chilled acetone and a pinch of magnesium carbonate was added to it. Extract was centrifuged at 2500rpm for 10 minutes. The process was repeated till the extract becomes colorless and the extracts were pooled. The volume was made up to 15mL. All the operations were carried in ice bath under dark conditions. The absorbance was measured at 645, 663, 750 nm using UV - Visible Spectrophotometer.

$TCh = [(20.2 \times A_{645} + 8.02 \times A_{663}) \times V] / 1000 \times W$

Where,

TCh = Total chlorophyll content in mgg^{-1}

A_{645} = Absorbance at 645nm- Absorbance at 750 nm

A_{663} = Absorbance at 663nm - Absorbance at 750 nm

V = volume of the final extract

W = weight of the sample

2.6 Determination of ascorbic acid

Ascorbic acid content was measured using spectrophotometric method (Lin and Ding,2008). About 1g of fresh leaf sample was weighed and homogenized with distilled water. To 25 mL of diluted sample, 2.5 mL of 5 % metaphosphoric acid was added and 2 drops of bromine water was added to oxidize ascorbic acid in dihydroform. The solution was centrifuged for 5 minutes and supernatant was collected for estimation of ascorbic acid after incubation at 37 ^{0}C for 3 h, followed by the addition of concentrated sulphuric acid using spectrophotometer the absorbance at 540 nm was noted.

2.7 Determination of relative water content

Relative water content was determined by the method of Singh, 1997. Fresh leaves were weighed and fresh weight was obtained. The leaves were then immersed overnight in water, blotted dry and then weighed to get the turgid weight. The leaves were then dried overnight in an oven at 70^{0}C and reweighed to obtain the dry weight.

RWC = (FW - DW) / (TW - DW) x 100

Where,

RWC = Relative Water Content in %

FW = fresh weight

TW = turgid weight

DW = dry weight

2.8 Air Pollution Tolerance Index

The APTI value was calculated by using the method of Singh and Rao (1983).

APTI = (AA (TCh + pH) + R) / 10

Where,

APTI = Air Pollution Tolerance Index

AA = ascorbic acid content (mgg^{-1})

TCh = total chlorophyll content (mgg^{-1})

PH = leaf extract pH

RWC = relative leaf water content of leaf (%)

3. RESULTS

Relative water content

The relative water content of the plants is presented in table 1. Relative water content of *Delonixregia*with 97.96 % was recorded to be the highest at the control place, whereas the least value was observed in *C.dactylon* (57.66%) at the industrial site followed by*D.regia*(69.62%),*T.chrysantha* (78.84%),*S.campanulata*(82.79%) and *R.communis*(87.12%).There was an overall reduction in relative water content among samples collected from polluted sites as compared to control. Maximum reduction was observed in industrial area which is the highly polluted site.

Table 1: Mean Relative Water Content (%) of plant species

Species	Control	Residential	Commercial	Industrial
C. dactylon	89.47±0.12	88.74±0.43	82.00±0.31	57.66±0.42
R. communis	84.67±0.35	90.78±0.39	83.12±0.23	87.12±0.32
T. chrysantha	95.17±0.28	78.68±0.24	83.17±0.45	78.84±0.16
S. campanulata	90.53±0.45	75.65±0.14	79.11±0.14	82.79±0.13
D. regia	97.96±0.14	83.86±0.42	76.96±0.51	69.62±0.44

n = 15

Total chlorophyll

The mean total chlorophyll content of plants is represented in table 2. Total chlorophyll content was recorded to be the highest in*Spathodeacompanulata*at the control site with 1.63 mgg^{-1} followed by *T. chrysantha*with 1.4 mgg^{-1}. The least chlorophyll content at the industrial site was observed in *D.regia* (0.88mgg^{-1}) followed by *R.communis* (1.11 mgg^{-1}) and *T. chrysantha*(1.11 mgg^{-1}). Similar to Relative water content, total chlorophyll content also decreased from control to polluted site with maximum reduction in industrial site.

Table 2: Mean Total Chlorophyll content (mgg^{-1}) of plant species

Species	Control	Residential	Commercial	Industrial
C. dactylon	1.14±0.056	0.92±0.132	0.78±0.113	1.02±0.009
R. communis	1.30±0.631	1.30±0.523	1.18±0.027	1.11±0.047
T. chrysantha	1.43±0.031	1.03±0.152	1.04±0.038	1.11±0.020
S. campanulata	1.63±0.253	1.09±0.074	1.29±0.065	1.21±0.028
D. regia	1.04±0.012	0.92±0.015	0.82±0.009	0.88±0.019

n = 15

pH of plants

The pH of *Tabebuiachrysantha*was found to be the highest compared to other plant species with 7.63 at the control area and observed to be the least in commercial place with 4.10 followed by the industrial place with 4.13. Highest pH at industrial area was shown by *Delonixregia* with 5.43. In general pH was alkaline in control site which declined towards acidic range in polluted areas (Table 3).

Table 3: Mean pH of plant species

Species	Control	Residential	Commercial	Industrial
C. dactylon	7.13±0.060	6.76±0.152	5.73±0.115	4.63±0.152
R. communis	6.34±0.399	6.23±0.1527	4.73±0.115	4.13±0.152
T. chrysantha	7.63±0.208	6.56±0.321	4.10±0.1	4.13±0.115
S. campanulata	6.83±0.057	6.72±0.107	5.16±0.152	5.03±0.152
D. regia	7.23±0.2081	7.1±0.1	5.43±0.11	5.53±0.30

n = 15

Ascorbic acid

Ascorbic acid content of the plants are given in table 4. Ascorbic acid content of *Spathodeacampanulata* was observed to be the highest in the control place with 0.63 mgg^{-1} and it was found to be decreased in industrial area and the least values in industrial area for ascorbic acid content was shown by *Tabebuiachrysantha*(0.01 mgg^{-1}). Ascorbic acid also showed a decreasing trend from control to polluted site.

Table 4: Mean Ascorbic Acid content (mgg^{-1}) of plant species

Species	Control	Residential	Commercial	Industrial
C. dactylon	0.25±0.34	0.11±0.11	0.18±0.10	0.013±0.25
R. communis	0.416±0.50	0.19±0.15	0.42±0.11	0.12±0.10
T. chrysantha	0.196±0.50	0.37±0.15	0.04±0.11	0.01±0.41
S. campanulata	0.63±0.57	0.39±0.11	0.04±0.32	0.036±0.30
D. regia	0.45±0.11	0.06±0.51	0.14±0.25	0.103±0.37

n = 15

Air Pollution Tolerance Index

The Air Pollution Tolerance Index (APTI) of plants decreased from control to polluted sites. The maximum reduction was observed in the highly polluted industrial area. The APTI of *C. dactylon* showed maximum decrease from control to highly polluted site. Followed by *D. regia*, *T. chrysantha, S. companulata*and *R. communis.* The mean per cent reduction of APTI over control showed highest reduction in *C. Dactylon*and least in *R. communis.*

Table 5: Air Pollution Tolerance Index of plant species

Species	Control	Residential	ROC (%)	Commercial	ROC (%)	Industrial	ROC (%)
C. dactylon	11.01	9.72	11.63	8.17	25.79	5.82	47.13
R. communis	11.73	10.55	10.05	10.99	6.30	9.35	20.28
T. chrysantha	10.77	10.66	1.02	8.52	20.89	7.93	26.36
S. campanulata	14.84	10.65	28.23	9.33	37.12	8.46	42.99
D. regia	13.42	8.86	33.97	8.58	36.06	7.58	43.51

n = 15

4. DISCUSSION

From the results, RWC was found to be higher in plants growing in control area and species in Industrial area held their lowest RWC. This showed that many species responded to the pollution by a RWC drop. *Delonixregia*showed highest value of RWC in the Control site followed by Residential area and Commercial area. The lowest value was recorded in *Cyanodondactylon*and *Ricinuscommunis* showed increased RWC in the Industrial area followed by Residential and Commercial area. Species such as *Ricinuscommunis* with higher RWC are tolerant to pollutants and plants with lower RWC such as *Cyanodondactylon* serve as sensitive species. Relative water content is an important factor which determines the physiological status of the plant. The relative water content is associated with protoplasmic permeability in cells. Loss of water and dissolved nutrients results in early senescence of leaves. The relative water content in a plant body helps in maintaining its physiological balance under stress conditions including air pollution stress (Dedio, 1975). The reduced relative water content indicates disturbed physiological status in the plants due to pollution (Ramakrishnaiah and Sonshekar, 2003).

Chlorophyll content was higher in *Ricinuscommunis*at the Control site and *Delonixregia* showed adecreased chlorophyll content compared to other plant species. The chlorophyll content was recorded to be intermediate in plants growing in the Residential area and the values decreased in plants growing in commercial area. The least values in chlorophyll content was recorded in plants at the Industrial area. Further it was observed that some individuals of species such as *Ricinuscommunis* and *Spathodeacampanulata*growing in polluted sites exhibited higher values of chlorophyll content indicating that air pollution has no marked effect upon the synthesis of chlorophyll pigment for these species. In plants such as *Delonixregia* and *Cyanodondactylon* lower amount of chlorophyll was observed. Speading and Taylor (1973), Santhoskumar and Paulsamy (2006) had reported that pollution stress decreases the chlorophyll level in plants. Also, plants appearing green and normal at low concentration of SO_2 show reduced efficiency of photosynthesis had been reported by Varshney (1982). Since chlorophylls are the chief photosynthetic pigments, their content signifies growth and development of biomass and overall health status of plants. Decrease in chlorophyll content has been suggested as an indicator of SO_2 pollution. High amount of gaseous SO_2 causes destruction of chlorophyll and that might be due to the replacement of Mg^{++} by two hydrogen atoms and degradation of chlorophyll molecules to phaeophytin (LeBlanc and Rao, 1966). A considerable loss of total chlorophyll in the plants exposed to pollutants supports the argument that the chloroplast is the primary site of attack by air pollutants such as SPM, SO_2 and NO_x. Pollutants such as SO_2, NO_2 and O_3 cause damage to membranes and associated molecules including chlorophyll pigments (Ramakrishnaiah and Sonshekar, 2003). Hence it is known that plants with high chlorophyll content are generally tolerant to air pollution.

The leaf extract pH was highest in *Tabebuiachrysantha* at the Control site followed by *Delonixregia*. Least values of leaf extract pH were shown by the plants growing in Industrial area. *Ricinuscommunis* and *Tabebuiachrysantha* showed decreased pH and *Delonixregia* showed higher value of pH in the polluted sites compared to other species indicating its tolerance to pollution. It was reported by Scholz and Reck (1977) that in the presence of an acidic pollutant the leaf pH is lowered and decline is greater in sensitive species. The presence of SO_2 and NO_X in the ambient air causes a change in pH of the leaf sap towards acidic range (Swami et al., 2004). Upon diffusion of SO_2 through stomata, gaseous SO_2 dissolves in water to form sulphites, bisulphate and their ionic species with the generation of protons influencing the cellular pH (Malhotra and Khan, 1984). It is therefore opined that the pH change towards acidic range observed in most species is due to entry of SO_2 into leaf mesophyll tissue.

Ascorbic acid content was recorded to be the highest in *Spathodeacampanulata* followed by *Ricinuscommunis* in the control site and the least values were shown by *Cyanodondactylon*and*Tabebuiachrysantha* in the Industrial area. Asorbic acid being a strong reductant together with leaf pH plays a significant role in determining SO_2sensitivity of plants (Chaudhary and Rao, 1977). Thus plants maintaining higher ascorbic acid content such as *Ricinuscommunis* and *Spathodeacampanulata* are considered to be tolerant to air pollution. The results of present study revealed that species exhibiting higher values of chlorophyll content also showed increased ascorbic acid content and they are considered to be tolerant to pollution. Reduction in ascorbic acid is attributed to increased rate of production of reactive oxygen species (ROS) during photo-oxidation of SO_2 to SO_3 (Jyothi and Jaya, 2010). Ascorbic acid is an antisorbic vitamin, strong reducing agent reported to play an important role in SO_2 reduction and it activates many physiological and defence mechanism, also maintains the stability of plant cell membranes during pollution stress. Its reducing power is directly proportional to its concentration (Raza and Murthy, 1988).

Depending on their sensitivity level the changes occur in the plants. All the four biochemical parameters namely, relative water content, ascorbic acid content, total chlorophyll and pH of leaves are crucial in determining the resistance and the susceptibility of different plant species to the polluted environment. The sensitive and tolerant species can be employed as air pollution sinks or as bio - indicators of pollution respectively, which to a great extent can help in mitigating the pollution. The results obtained from the present study revealed that plants show specific response to air pollutants and different plants show different responses to the air pollutants. The APTIs of the plants, *Ricinuscommunis*, *Spathodeacampanulata* was found to be higher in polluted sites than those of other species suggesting these plants to be more tolerant to air pollution and Cyanodondactylon showed lower APTI value in the polluted sites compared to the other species. Species ranked as intermediately tolerant can be chosen for planting only when these have strong ability to absorb the air pollutants. Such plants can be effectively used as indicators and pollution scavengers (Singh and Rao, 1983; Agarwal, 1989; Tiwari, 1991; Paulsamy et al., 2006; Thanbavani et al., 2009). Hence these species of higher APTI can be used for plantation in and around industrial complexes, road sides and urbanized areas so as to reduce the effect of air pollution. Many reports have indicated that the species with low index values are sensitive to air pollution and *vice versa* (Lakshmi et al., 2008; Begum and Harikrishna, 2010; Thambavani and Sabitha, 2011). The level of APTI exclusively depends on the intrinsic nature of each species since the level of total chlorophylls, ascorbic acid, pH and relative water contents varies greatly from species to species and they are not directly comparable. It is important to draw conclusions based on the differences in the amount of changes (%ROC) observed within the species.

Air pollution tolerance index values were found to be greater in *Ricinuscommunis* in polluted sites compared to other plant species showing tolerance towards different pollutants and the least in *cyanodondactylon*which showed sensitivity to the pollution. Higher APTI values for *Ricinuscommunis* was also reported by Karthiyayini et al., (2005).

From the present study it can be inferred that, *Cyanodondactylon*being sensitive species, can be used as an indicator and *Ricinuscommunis*exhibiting tolerance to the ambient air pollution, can be used as a sink of air pollution.

5. CONCLUSION

Road traffic serve as a substantial source of environmental pollution and exert changes in various physiological parameters in plants such as total chlorophyll content, ascorbic acid content, pH and relative water content. APTI determination provides a reliable method for screening large number of plants with respect to their response to air pollutants. APTI determination of plants is important because in recent century by increasing industrialization, air pollution is threatening the environment.The species *Cynodondactylon*can be used as a bioindicator, it showed least percentage reduction over its control counterpart, while *Ricinuscommunis*can be used as a sink to air pollution.Important point to note is that both the species are widely spread in urban areas.

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