Roadside Plants as Bio-indicators of Urban Air Pollution

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ABSTRACT

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This paper describes air pollution tolerance among roadside plants exposed to varying degrees of vehicular pollutants. Evaluation of air pollution tolerance index (APTI) of 10 selected wild plant species was carried out to assess their response to ambient levels of air pollutants along the busy roadways of Ahmednagar. Four parameters namely total chlorophyll, ascorbic acid, pH of leaf extract and relative water content were determined and computed together to signify air pollution tolerance index (APTI) of plants. The observed significant reduction in total chlorophyll, ascorbic acid and relative water content showed inverse relationship with traffic density. Similarly, pH of leaf extract followed an exponential decrease with increase in traffic density and drifted towards acidic range. Comparison of APTI values from control to polluted sites revealed maximum reduction in *Bougainvillea spectabilis* while least change was noted in *Peltophorum pterocarpum*. Among the plants studied maximum net per cent reduction of APTI over control was seen in *Bougainvillea spectabilis* and *Ageratum conyzoides* and are considered to be sensitive species. While *Peltophorum pterocarpum* and *Portulaca oleraceae* are tolerant species since they have shown least per cent reduction in APTI.

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I. INTRODUCTION

The atmosphere is a complex and dynamic gaseous system that is essential to support life on planet Earth. Rapid industrialization and urbanization coupled with increase in vehicular traffic in the urban areas has become a great threat to air quality, threatening the very existence of the living beings. Among the various categories, air pollution by automobiles is the

most insidious one, which exerts highly detrimental effects on living organisms. Ambient air pollution in several large cities of India is amongst some of the highest in the world]. Among various strategies of controlling atmospheric pollution, absorption of gaseous pollutants by plants provide one of the natural ways of cleansing the atmosphere and they act as effective indicators of air pollution. Recent studies have explored the possibility to find out the ability of

plants to remove and also act as sinks for air pollutants Bio-monitoring is a low cost and valuable method to evaluate the effect of different air and environment pollutants There is hardly any data available on plants which act as sensitive, tolerant and resistant species to urban pollution, particularly vehicular pollution. The air pollution tolerance index (APTI) based on four parameters, namely total chlorophyll, ascorbic acid, pH and relative water content have been used for identifying tolerance levels of these species APTI has been extensively used to rank plant species in their order of tolerance to air pollution In a similar attempt the present study was carried out to assess APTI of 10 angiospermic plants covering the busy roadways of Ahemadnagar city.

II. MATERIALS AND METHODS

2.1 Study site – Study Area The Ahemadnagar district is located between 18°02'N lat., 19°09' E North latitude and 73°05' and., 75° 05' East longitude and is situated partly in the upper Godavari river basin and partly in the Bhima river basin It is largest district of Maharashtra occupying more or less the central position in the state and with an area of 17,413 sq. km. As regards the botanical explorations in Ahmednagar. The sites selected for the present study includes a control site (Gorakhnathgad S I), a moderately polluted residential site (M I R C - S II) and a highly polluted site (city railway station - S III) having an approximate traffic density plants were collected and analyses for the following parameters.

2.2 Plants

2.3. Total chlorophyll The total chlorophyll was estimated principally by the method of Arnon [10]. One gram fresh leaf was macerated with 80% (v/v) chilled acetone and a pinch of magnesium carbonate in a pre-chilled pestle and mortar. The extract was centrifuged at 2500 rpm for 10 minutes. The process was repeated till the extract becomes colourless and

the extracts were pooled and the volume was made up to 15mL. All operations were carried in the ice bath under dark condition. The absorbance was measured at 645, 663 and 750nm using UV-visible spectrophotometer.

$$TCh = \frac{20.2(A_{645}) + 8.02(A_{663}) \times V}{1000 \times W}$$
 Where, TCh= Total chlorophyll in mgg-1 A_{645} = Absorbance at 645nm minus the absorbance at 750nm A_{663} =Absorbance at 663nm minus the absorbance at 750nm V = Total volume of the extract in mL W = Weight of the sample in g

Sr. No.	Name of the plant	Family	Plant part used
1	Ageratum conyzoides L	Asteraceae	Fresh leaf samples
2	Bambusa bambos L. Voss	Poaceae	Fresh leaf samples
3	Bougainvillea spectabilis Comm. Ex. Juss.	Nyctaginaceae	Fresh leaf samples
4	Cynodon dactylon L. Pers.	Poaceae	Fresh leaf samples
5	.Ficus religiosa L..	Moraceae	Fresh leaf samples
6	Mangifera indica L	Anacardiaceae	Fresh leaf samples
7	Peltophorum pterocarpum DC. K. Heyne	Fabaceae	Fresh leaf samples
8	Portulaca oleraceae L	Portulacaceae	Fresh leaf samples
9	Ricinus communis L.	Euphorbiaceae	Fresh leaf samples
10	Terminalia catappa L.	Combretaceae	Fresh leaf samples

2.4. Ascorbic acid One gram fresh leaf was homogenized in 4mL of freshly prepared oxalic acid (0.4% w/v), filtered and centrifuged at 1000 rpm for 20 minutes. Final volume was made up to 10mL using oxalic acid. About 5mL of the extract was titrated against standardized 2,6-dichlorophenol-indophenol [11]. $AA = I \times S \times D / A \times 1 / W$ Where, AA = Ascorbic acid in mgg-1 I = mL of indophenol used for titration S = mg of ascorbic acid reacting with 1mL indophenol D = total volume of the extract in mL A = Aliquot titrated in mL W = Weight of the sample in g

2.5. Relative Water Content The fresh weight of the leaves was determined and immersed in water over night. Turgid weights of the leaves were measured after blotting the leaves. The leaves were dried overnight in an oven at 80°C and the dry weight was determined $RWC = (F - D / T - D) \times 100$ Where, RWC = Relative water content in % F = Fresh weight in g T = Turgid weight in g D = Dry weight in g

2.6. pH of the leaf samples Five grams of fresh leaves were homogenized in 10mL deionised water. This was filtered and the pH of the leaf extract was determined after calibrating pH meter using buffer solution

2.7. APTI The air pollution tolerance indices were determined following the method of Singh and Rao [7]. $APTI = AA(TCh + pH) + RWC / 10$ Where, APTI = Air pollution tolerance index AA = ascorbic acid content in mgg-1 TCh = total chlorophyll in mgg-1 pH = pH of leaf extract RWC = relative water content in %

3.1. Total chlorophyll The concentration of total chlorophyll decreased in all the species growing at polluted sites when compared to the controls, with maximum reduction at S III which harbours highest vehicular density. Maximum total chlorophyll reduction was seen in *Bougainvillea spectabilis* and *Portulaca oleraceae*, moderate reduction in *Peltophorum pterocarpum*, *Ricinus communis* and *Ficus religiosa*, while minimum reduction was observed in *Mangifera indica*, *Bambusa bambos* and *Cynodon dactylon*. 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 SO₂ pollution. High amount of gaseous SO₂ 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] 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, SO₂ and NO_x. Pollutants such as SO₂, NO₂ and O₃ cause damage to membranes and associated molecules including chlorophyll pigments.

Table 1: Mean concentration of total chlorophyll and ascorbic acid of selected plant species at different sites

Plants	Total chlorophyll (mgg ⁻¹)			Ascorbic acid (mgg ⁻¹)		
	S I	S II	S III	S I	S II	S III
<i>A. conyzoides</i>	2.443±0.023	1.823±0.260	1.643±0.296	0.263±0.291	0.216±0.092	0.142±0.208
<i>B. bambos</i>	1.991±0.156	1.610±0.301	1.382±0.316	0.111±0.256	0.098±0.276	0.093±0.104
<i>B. spectabilis</i>	2.901±0.347	1.899±0.098	1.544±0.089	0.433±0.333	0.311±0.198	0.081±0.273
<i>C. dactylon</i>	2.050±0.256	1.523±0.125	1.401±0.059	0.158±0.089	0.121±0.387	0.101±0.124
<i>F. religiosa</i>	2.512±0.176	1.645±0.287	1.584±0.138	0.150±0.302	0.102±0.207	0.083±0.242
<i>M. indica</i>	2.822±0.067	2.237±0.311	2.086±0.207	0.210±0.099	0.189±0.088	0.159±0.255
<i>P. pterocarpum</i>	2.527±0.219	1.664±0.200	1.512±0.273	0.222±0.103	0.198±0.276	0.142±0.087
<i>P. oleraceae</i>	2.926±0.311	2.086±0.291	1.635±0.345	0.197±0.168	0.148±0.157	0.132±0.182
<i>R. communis</i>	2.323±0.249	2.088±0.089	1.403±0.301	0.261±0.298	0.255±0.298	0.232±0.076
<i>T. catappa</i>	2.401±0.110	1.895±0.196	1.601±0.204	0.116±0.345	0.102±0.289	0.093±0.156

n=15

Table 2: Mean concentration of pH of leaf extracts and relative water content of selected plant species at different sites

Plants	pH			Relative water content (%)		
	S I	S II	S III	S I	S II	S III
<i>A. conyzoides</i>	6.71±0.302	6.14±0.142	5.43±0.086	85.95±0.124	71.72±0.134	68.81±0.148
<i>B. bambos</i>	5.68±0.178	5.24±0.257	5.31±0.244	45.37±0.323	36.36±0.366	34.21±0.198
<i>B. spectabilis</i>	5.76±0.079	5.00±0.278	4.74±0.194	67.41±0.258	53.10±0.234	49.20±0.234
<i>C. dactylon</i>	6.71±0.355	6.45±0.340	6.26±0.350	25.12±0.209	21.40±0.098	20.36±0.246
<i>F. religiosa</i>	7.59±0.198	7.01±0.089	6.43±0.254	75.97±0.136	61.10±0.124	55.98±0.378
<i>M. indica</i>	6.93±0.154	6.59±0.129	6.02±0.187	73.97±0.378	61.71±0.186	52.02±0.093
<i>P. pterocarpum</i>	7.01±0.257	6.68±0.108	6.01±0.108	69.23±0.214	62.14±0.099	50.54±0.355
<i>P. oleraceae</i>	6.80±0.224	6.62±0.386	6.40±0.088	76.23±0.125	70.14±0.100	64.26±0.236
<i>R. communis</i>	5.76±0.197	5.70±0.134	5.32±0.148	88.44±0.263	78.76±0.189	70.16±0.248
<i>T. catappa</i>	5.50±0.173	5.48±0.284	5.39±0.247	68.71±0.298	58.21±0.294	52.22±0.248

n=15

III. RESULTS AND DISCUSSION

The results of analysis of total chlorophyll and ascorbic acid are presented in table 1 and pH of leaf extract and relative water content table 2.

3.2. Ascorbic acid Traffic density dependent decrease in ascorbic acid content of all the species was noted. Maximum reduction in ascorbic acid content was recorded in *Bougainvillea spectabilis*, *Ageratum conyzoides* and *Ficus religiosa*, moderate reduction was noted in *Cynodon dactylon*, *Peltophorum pterocarpum* and *Portulaca oleraceae*. While *Ricinus communis*, *Bambusa bambos*, *Terminalia catappa* showed least reduction. Reduction in ascorbic acid is attributed to increased rate of production of reactive oxygen species (ROS) during photo-oxidation of SO₂ to SO₃. Ascorbic acid is an antioxidant vitamin, strong reducing agent reported to play an important role in SO₂ 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.

3.4. pH All the plant samples collected from polluted site exhibited a shift in pH towards acidic range. High acidic pH was found in *Bougainvillea spectabilis* (4.74), *Bambusa bambos* (5.31) and *Ricinus communis* (5.32). The presence of SO₂ and NO_x in the ambient air causes a change in pH of the leaf sap towards acidic range. Upon diffusion of SO₂ through stomata, gaseous SO₂ dissolves in water to form sulphites, bisulphate and their ionic species with the generation of protons influencing the cellular pH. It is therefore opined that the pH change towards acidic range observed in most species is due to entry of SO₂ into leaf mesophyll tissue.

3.3. Relative water content Plants growing in polluted site showed reduced relative water content, with maximum reduction in *Mangifera indica*, *Bougainvillea spectabilis*, moderate reduction was observed in *Peltophorum pterocarpum*, *Ficus religiosa*, *Bambusa bambos* and minimum reduction in *Portulaca oleraceae* and *Cynodon dactylon*. 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]. The reduced relative water content indicates disturbed physiological status in the plants due to pollution.

3.5. Air Pollution Tolerance Index The calculated APTI decreased progressively from control to highly polluted sites, table 3

Table 3: APTI and their per cent reduction over control (%ROC)

Plants	S I APTI	S II APTI	S III APTI	% ROC
<i>Ageratum conyzoides</i>	9.15	6.48	5.12	44.06±0.251
<i>Bambusa bambos</i>	4.62	3.70	3.48	24.64±0.109
<i>Bougainvillea spectabilis</i>	9.21	5.52	4.57	50.41±0.307
<i>Cynodon dactylon</i>	2.65	2.33	2.27	14.22±0.298
<i>Ficus religiosa</i>	7.74	6.19	5.66	26.87±0.273
<i>Mangifera indica</i>	8.60	6.33	5.03	41.51±0.271
<i>Peltophorum pterocarpum</i>	7.13	6.67	6.36	10.84±0.346
<i>Portulaca oleraceae</i>	7.81	7.16	6.93	11.28±0.271
<i>Ricinus communis</i>	8.90	8.07	8.07	19.43±0.192
<i>Terminalia catappa</i>	6.96	5.94	5.28	24.13±0.278

n=15

IV. CONCLUSION

Air pollution has been considered as a potential selection force for plants, therefore the species growing in such adverse roadside environment present the best material to ascertain the levels of susceptibility rather than drawing interpretations from measurements obtained from lab conditions. Furthermore, APTI determination provides a reliable method for screening large number of plants with respect to their response to air pollutants.

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