AIR POLLUTION TOLERANCE INDEX (APTI) OF VARIOUS PLANT SPECIES GROWING IN QUETTA CITY, PAKISTAN

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Abstract

This study focuses on the determination of Air Pollution Tolerance Indices (APTI) from twelve plant species growing along polluted site (the road side of Quetta city) and non-polluted site (Botanical garden University of Balochistan, Quetta). The APTI was determined by synthesizing the four different physiological and biochemical parameters i.e. leaf relative water content (RWC), ascorbic acid content (AA), total leaf chlorophyll (TCh) and pH of leaf extract. The plant species selected for the study were *Fraxinus xanthoxyloids, Robinia pseudoaccacia, Vitis vinifera, Pistacia atlantica, Rosa indica*, *Melia azadirachta, Punica granatum, Morus alba, M. nigra, Prunus armeniaca, Euclaptus terticornis and Ficus carica*. Air Pollution Tolerance Index (APTI) was found higher in the plant samples of polluted sites compared to the non polluted sites. The results showed that decrease in total chlorophyll content was recorded in the leaf samples of all selected trees collected from polluted sites whereas the increased values were recorded in the leaf samples of non polluted sites. The maximum reduction (40.39%) of total chlorophyll content was recoded in the leaves of *Prunus armeniaca* and minimum reduction (4.48 %) was in the leaves of *Morus alba* of polluted site. There was maximum increament of relative water content (38.87%) in the leaves of *Fraxinus xanthoxyloids* and minimum increase (4.19%) was found in the leaves of *Vitus vinifera* of the polluted site. Ascorbic acid contents showed maximum value (39.13 %) in the leaves of *Ficus carica* and minimum amount (18.75 %) was recorded in the leaves of *Vitis vinifera* of the samples collected from polluted site. The maximum pH (6.85 ± 1.00) was observed in the leaves of *Vitis vinifera* and minimum value (5.44± 0.86) was observed in the leaves of *Morus nigra* of polluted site. The results were further statistically analyzed by using t-test showed significantly high level of pollution at the pollution sites, in all the parameters studied mainly due to automobile exhaust.

Introduction

Air pollution can be defined as the human interference into the atmosphere this may be of chemicals, particulate matter or biological materials that cause harm or discomfort to human health, or other living organism or damage the environment (Anonymous, 2008). Air pollutions can directly affect plants via leaves or indirectly via soil acidification (Steubing, *et al.,* 1989). It has also been reported that when exposed to air pollutants, most plant experience physiological changes before exhibiting visible damage to leaves (Dohmen *et al.,* 1990). Air pollution in urban areas if hoard or amalgamate in the plant body, may harmed them in various ways. The intensity of injury depends on the sensitivity of the plant species. For this purpose, the valuation of plants with respect to their APTI may be essential because with increase industrialization, there is increasing danger of deforestation due to air pollution.. Studies have also shown the impacts of air pollution on Ascorbic acid content, chlorophyll content, leaf extract, pH and Relative water content (Hoque *et al.,* 2007; Flowers *et al.,* 2007; Klumpp *et al.,* 2000 and Rao, 1979). Several contributors agree that the plant growth is adversely affected by air pollutants (Rao, 2006; Bhatia, 2006; Sodhi, 2005, Horsefall, 1998). Air pollution tolerance index is used by landscapers to select plant species tolerance to air pollution (Yan-J and Hui, 2008). APTI has also been used to rank plant species in their order of tolerance to air pollution (Raza and Murthy, 1988; Singh and Rao, 1983).

In the present study APTI of growing plants in polluted and non-polluted areas of Quetta city have been investigated. It is hoped that this study may help in proper selection of the plants for urban plantation and will assist to evaluate the resistance levels of various plants.

Materials and Methods

The study was carried out on twelve plant species growing along polluted and non-polluted sites during the year 2009-2010. The road side was selected as a polluted area for case study, because numerous sources emit dust and smoke including vehicles. Biological garden university of Baluchistan with similar ecological conditions was selected as the non polluted area. Plants at different strata such as trees, shrubs and climbers were selected for the present study.

The plants selected for the study were those available at both sites. The leaf samples of different species of trees, shrubs and climbers of Quetta city were collected from isoecological conditions (light, water and soil) and immediately brought to the laboratory. Three replicates of fully mature leaves of each species were collected. A composite sample of each plant species was obtained before analysis. The leaf fresh weight was taken immediately upon getting to the laboratory and then process for other parameters.

The APTI was determined by calculating the Relative Water Content (RWC), Ascorbic Acid (AA), Total Chlorophyll Content (TCC) and pH in leaf samples. Ascorbic acid content (mg/g) was measured using spectrophotometer method (Bajaj and Kaur, 1981). Chlorophyll, pH and Relative water content of leaf material was estimated by following the method Agbaire and Esiefarienrhe, (2009). The Air Pollution Tolerance Indices of twelve common plants were determined by following the method of Singh and Rao, (1983). The formula of APTI is given as;

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

Where, APTI = Air Pollution Tolerance Indices, A = Ascorbic acid content (mg/g), T = total chlorophyll (μg/gfw), P = pH of leaf extract, and R = relative water content of leaf (%). The entire sum was divided by 10 to obtain a small manageable figure.

Results and Discussion

In this study, changes in parameters such as total chlorophyll content, ascorbic acid, relative water content and pH of leaf extract were used to evaluate the degree of tolerance to air pollution by the plant species.

The mean concentration of Ascorbic acid in leaves of polluted and non-polluted areas is summarized in Table 1. The maximum increasing percentage of ascorbic acid (39.13 %) was observed in the leaves of *Ficus carica* and minimum increasing percentage (18.75 %) was observed in the leaves of *Vitis vinifera* of polluted site (Table 2). Under polluted area of Quetta city, the ascorbic acid concentration was found higher than those of the non polluted area. Ascorbic acid is concentrated mainly in chloroplasts (Franke and Heber, 1964) it is a natural antioxidant in plants in pollution tolerance (Chen *et al*., 1990). The t-values indicate that increase of ascorbic acid content in the leave samples collected from polluted sites in comparison with non polluted sites was significantly high at $p<0.05$. Similar observation was also made by Agbaire & Esiefarienrhe, (2009). Ascorbic acid is a strong reductant and it activates many physiological and defence mechanism. Its reducing power is directly proportional to its concentration (Raza and Murthy, 1988). However it's reducing activity is pH dependent, being more at higher pH levels.

Table 2 describes the total mean chlorophyll concentration in the plant leaves of both polluted and non-polluted areas. The results revealed that the total chlorophyll contents was found low in the leave samples collected from polluted sites of Quetta city compared to the non polluted site in all the investigated plant species. Highest reduction (40.39%) of total chlorophyll contents was recorded in *Prunus granatum* whereas least reduction (4.48 %) was found in the leaves of *Morus alba* at polluted site. The t-test shows that reduction in total chlorophyll contents of polluted sites were significantly higher (at $p<0.05$) when compared with non-polluted sites (Table 1). The observations of Agbaire and Esiefarienrhe, (2009) also support these results. According to Raza and Murthy (1988) Chlorophyll is an index of productivity of plant whereas certain pollutants decrease the total chlorophyll content (Allen *et al*., 1987). The concentrations of total chlorophyll content were always found to be lower at polluted site compared to non polluted sites even in the leaves of the same age (Chauhan and Joshi, 2008). Rao and Leblanc, (1966) have also reported reduction in chlorophyll content brought by acidic pollutants like SO2 which causes phaeophytin formation by acidification of chlorophyll. Reductions in chlorophyll content in a variety of crop plants due to NO2, SO2 and O3 exposure have also been reported by Agrawal *et al*., (2003). Lerman (1972) has suggested that continuous application of cement dust close the stomata so the interfering the gaseous exchange and reduces the chlorophyll contents. Polluted site of Quetta is in the grip of serious air pollution due to dust and smoke emitted by the vehicles.

The change in pH in the leaf samples collected from the polluted sites were significant at 0.05 probability levels in ten plant species except two species i.e. *Vitis vinifera* and *Rosa indica* (Table 3). All the plant samples collected from polluted sites exhibited a pH towards acidic side, which may be due to the presence of SO_x and NO_x in the ambient air causing a change in pH of the leaf sap towards acidic, Swami et al., 2004 also observed similar results. Low leaf pH extract showed good correlation with sensitivity to air pollution and also reduces photosynthetic process in plants (Yan and Hui , 2008).

Table 1. Ascorbic acid (mg/g) concentration in the plant leaves of polluted and non pollutedsites of Quetta city

Name of Plants	Plant site with AA (mg/g)		Increasing %	t-values
	Polluted mean ± S.D	Non polluted mean ± S.D		
Fraxinus xanthoxyloids	0.16 ± 0.02	0.11 ± 0.08	31.25	1.35
Robinia pseudoaccacia	0.14 ± 0.04	0.10 ± 0.07	28.57	1.06
Vitis vinifera	0.16 ± 0.03	0.13 ± 0.09	18.75	1.26
Pistacia atlantica	0.13 ± 0.01	0.09 ± 0.06	30.76	1.68
Rosa indica	0.15 ± 0.02	0.10 ± 0.07	33.33	1.57
Melia azadirachta,	0.12 ± 0.02	0.09 ± 0.07	25.00	0.99
Punica granatum	0.14 ± 0.03	0.10 ± 0.07	28.57	1.15
Morus nigra	0.19 ± 0.01	0.12 ± 0.09	36.84	1.64
Morus alba	0.18 ± 0.03	0.12 ± 0.09	33.33	1.30
Prunus armeniaca	0.15 ± 0.02	0.10 ± 0.07	33.33	1.62
Eucalaptus terticornis	0.16 ± 0.03	0.12 ± 0.09	25.00	0.85
Ficus carica	0.23 ± 0.03	0.14 ± 0.10	39.13	1.38

Significant at: *$p < 0.05$, Df= Degrees of freedom (4), S.D = Standard deviation, tc = Calculated values in t-test, AA = Ascorbic acid

Table 2. Total Chlorophyll Concentration (µg/gfw) in the plant leaves of polluted and non polluted sites of Quetta city

Name of Plants	Plant site with TCh (µg/gfw)		Reduction %	t-values
	Polluted mean ± S.D	Non polluted mean ± S.D		
Fraxinus xanthoxyloids	72.27 ± 1.17	81.27 ± 3.59	11.07	1.58*
Robinia pseudoaccacia	72.12 ± 2.12	78.25 ± 1.99	7.83	2.04*
Vitis vinifera	75.99 ± 2.11	82.3 ± 3.52	7.68	0.99
Pistacia atlantica	27.71 ± 3.34	32.75 ± 1.94	15.38	0.71
Rosa indica	28.08 ± 2.46	31.22 ± 3.45	10.05	0.49
Melia azadirachta,	71.40 ± 2.76	77.74 ± 2.02	8.15	1.52
Punica granatum	38.51 ± 3.50	42.30 ± 1.94	8.95	0.66
Morus nigra	31.24 ± 3.00	35.47 ± 2.01	11.90	0.90
Morus alba	70.23 ± 5.00	73.53 ± 2.50	4.48	0.29
Prunus armeniaca	10.94 ± 4.13	18.36 ± 3.01	40.39	0.80
Eucalyptus terticornis	29.63 ± 5.04	32.78 ± 2.52	9.60	0.27
Ficus carica	24.80 ± 5.05	27.56 ± 2.05	9.66	0.25

Significant at: *$p < 0.05$, Df = Degrees of freedom (4), S.D = Standard deviation, tc = Calculated values in t-test, TCh= Total Chlorophyll Concentration *=significantly different

Table 3. pH level in the plant leaves of polluted and non polluted area of Quetta city

Name of Plants	Plant site with pH		Increasing %	t-values
	Polluted mean ± S.D	Non polluted mean ± S.D		
Fraxinus xanthoxyloids	6.31 ± 1.16	4.73 ± 0.73	33.40	2.35*
Robinea pseudoaccacia	6.20 ± 1.26	4.84 ± 0.55	28.10	2.03
Vitis vinifera	6.85 ± 1.00	4.90 ± 0.73	39.80	3.57*
Pistacia atlantica,	5.46 ± 0.95	4.57 ± 0.78	19.47	1.67
Rosa indica	6.75 ± 0.99	4.81 ± 0.36	40.33	4.89*
Melia azadirachta,	5.91 ± 1.82	5.15 ± 0.35	14.76	0.62
Punica granatum	5.93 ± 0.74	5.24 ± 0.86	13.17	1.49
Morus nigra	5.44 ± 0.86	4.95 ± 0.60	9.90	1.25
Morus alba	5.76 ± 0.98	4.62 ± 0.70	24.68	2.21
Prunus armeniaca	5.54 ± 1.18	4.46 ± 0.88	24.22	1.40
Eucalaptus terticornis	5.51 ± 1.46	5.11 ± 0.58	7.83	0.45
Ficus carica	5.68 ± 0.72	4.91 ± 0.71	15.68	2.07

Significant at: *$p < 0.05$, Df = Degrees of freedom (4), S.D = Standard deviation
tc = Calculated values in t-test , RWC= Relative Water Content

Table 4: Relative Water Content (%) in plant leaves of polluted and non polluted areas in Quetta city

Name of Plants	Plant site with RWC (%)		Increasing %	t-values
	Polluted mean ± S.D	Non polluted mean ± S.D		
Fraxinus xanthoxyloids	89.63 ± 4.03	54.78 ± 5.08	38.87	2.34*
Robinia pseudoaccacia	87.07 ± 7.07	75.16 ± 5.06	13.67	0.44
Vitis vinifera	87.39 ± 7.09	83.72 ± 3.01	4.19	0.17
Pistacia atlantica	85.25 ± 5.05	78.16 ± 1.84	8.31	0.69
Rosa indica	84.38 ± 3.25	78.90 ± 2.05	6.50	1.05
Melia azadirachta,	75.14 ± 2.04	70.51 ± 2.52	6.16	1.24
Punica granatum	87.21 ± 2.01	77.34 ± 2.04	11.31	1.24
Morus nigra	85.44 ± 3.01	78.18 ± 2.98	8.4	1.14
Morus alba	77.22 ± 3.34	64.09 ± 3.03	17.00	1.82
Prunus armeniaca	77.60 ± 1.95	67.52 ± 2.98	12.98	2.23*
Eucalaptus terticornis	101.32 ± 1.77	102.99 ±1.74	-1.65	0.76
Ficus carica	96.30 ± 1.84	85.71 ± 6.38	10.99	0.67

Significant at: *$p < 0.05$, Df = Degrees of freedom (4), S.D = Standard deviation, tc= Calculated values in t-test

Table 5: Air Pollution Tolerance Index (APTI) of some Plant species of polluted and non polluted of Quetta city

Name of Plants	Plant site with APTI		Increasing %
	Polluted	Non polluted	
Fraxinus xanthoxyloids	10.22	6.42	59.09
Robinia pseudoaccacia	9.80	8.35	17.45
Vitis vinifera	10.40	9.51	9.36
Pistacia atlantica	8.96	8.15	9.87
Rosa indica	8.96	8.25	8.62
Melia azadirachta,	8.44	7.80	8.27
Punica granatum	9.34	8.21	13.81
Morous nigra	9.24	8.30	11.30
Morous alba	9.09	7.35	23.72
Prunus armeniaca	8.01	6.98	14.70
Eucalaptus terticornis	10.69	10.75	-0.56
Ficus carica	10.33	9.03	14.49

Relative water content of all the plant species collected from polluted sites were significantly higher compared to non-polluted site at $p<0.05$ probability levels using t-tests (Table 4). There was maximum value of RWC (38.87%) was estimated in the leaves of *Fraxinus xanthoxyloids* whereas the minimum value (4.19%) was observed in the leaves of *Vitus vinifera* of polluted site whereas *Eucalyptus terticornis* shows negative reduction(-1.6515 %) at polluted site. The negative decrease of relative water content in the leaves of *Euclaptus terticornis* from the polluted site might be due to low turgid weight compared to the fresh weight. When the leaves were immersed in water overnight the leaves of *Eucalaptus terticornis* loose their weight instead of gain which is very unusual result (Table 3). Higher water content was also observed by Paulsamy *et al.,* (2000) in *A. indica.* High water content with a plant body may help to maintain its physiological balance under air pollution stress condition. High relative water content indicated drought resistance in plants (Dedio, 1975). It also helps to maintain the physiological balance under stressed conditions.

Table 5 showed that there was significant increase in APTI of polluted sites compared to the non polluted sites. The maximum value (59.08%) of APTI was recorded in the leaves samples of *Fraxinus xanthoxyloids* and minimum value (-0.55579%) was found in *Eucalaptus terticornis*. Similar observation was also noted by Agbaire and Esiefarienrhe, (2009) and Agbaire, (2009). Air pollution tolerant index is an index denotes capability of a plant to combat against air pollution. Plants which have higher index value are tolerant to air pollution and can be caused as sink to control pollution, while plants with low index value show less tolerance and can be used to indicate levels of air pollution (Singh and Rao, 1983). The plants being constantly exposed to the environment absorbs, accumulation integrate pollutants impinging on their foliar surfaces. Consequently they show visible or subtle changes depending on their sensitivity level (Smith, 1975). They further reported that depending on their sensitivity level, plants show visible changes which would include alteration in the biochemical processes or accumulation of certain metabolites.

An overview of the entire result obtained from this study indicates that different plants differently respond to air pollution, hence the different indices it is obtained that plants growing in polluted environment have higher APTI than less polluted environment. From the result obtained, it has been observed that *Fraxinus xanthoxyloids, Morus alba, Robinia pseudoaccacia, Prunus armeniaca Ficus carica* and *Punica granatum* were the more tolerant species since they had the least percentage increase in APTI values (Table 5). The results of the studies are therefore recommended that tolerant plant species serve as sink to air pollutants as well as work to indicate the polluted and less polluted areas.

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