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Assesment of Air Pollution Tolerance Index of Higher Plants Suitable for Green Belt Development in East of Esfahan City, Iran

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Abstract

Development of a green belt with suitable plant species around the source of emission can mitigate the atmospheric contamination. Selection of such plant species are required to combat air pollution based on their tolerance level. Present study was undertaken to evaluate the tolerance level of higher plants in East of Esfahan city, Iran, during 2011 in terms of assessing Air Pollution Tolerance Index (APTI). Leaf extract of nine plant species showed elevated levels of pH, ascorbic acid, chlorophyll and relative water content. Stress metabolites like ascorbic acid and chlorophyll of certain plant species exhibits different levels of sensitivity and tolerance towards air pollution. Dust deposition on leaf surfaces was estimated to observe the extent of particulate deposition. The highest and the lowest deposition rates were observed in Morus alba and *Cercis siliquastrum*, respectively. Among the nine different plant species examined, APTI value is maximum in Morus alba suggesting its higher tolerance.

Keywords: Air pollution, Air pollution tolerance index (APTI), Esfahan city, Higher plants.

INTRODUCTION

Most of the urban areas of the world today have high concentrations of air pollutants emanating from different sources viz, motor vehicle, traffic, power generation, residential heating and industry of adjoining areas (Lopez *et al.*, 2005). These sources are basically resulting from rapid economic growth, industrialization, urbanization with associated increase in energy demands (Madhavi and Badarinath, 2005). These urban air pollutants not only represent a threat to human health and the urban environment but it can also contribute to serious regional and global atmospheric pollution problem. Among the air pollutants, air borne particulates specifically trace elements and heavy metals constitute the major pollutant burden in urban environment, which needs to be monitored, filtered and regulated (Kar *et al*., 2006; 2010). With regard to the mitigation of these severe problems, policy should be adopted to control the pollution burden by means of monitoring, filtering and regulating the pollutants and their proper management. One of the important technique is the urban plantation and green belt development with suitable plant species in appropriate manner which is highly imperative to biofilter the toxic pollutants as well as other economic value (Sumita *et al.*, 2003; Munshi *et al.,* 2001).

It is an established fact that vegetation plays an important role in cleaning the atmosphere by absorbing certain toxic air pollutants from its surroundings and also abatement of noise pollution (Harju *et al*., 2002; Agarwal and Agarwal, 2000). Thus Green belts are recommended for containment of air pollution in the human environment, especially in urban and industrial environment. Model for green belt development is recently developed in relation to pollution around industrial premises (Smodis *et al.*, 2004). In addition, there were number of other benefits like aesthetic improvement, climatic amelioration, biomass generation, enhancement of biodiversity etc. are the bonus derived through the presence of greenery in the areas. In urban region of Iran, it has become mandatory for large scale polluting industry to plant appropriate green belts in and around its unit to protect surrounding ecology.

Plants remove air pollutants primarily by uptake via leaf stomata and once inside the leaf, gases diffuse into intercellular spaces and absorbed by water films. Plants, grown in such a way as to function as pollutants sinks are collectively referred to as greenbelts which have limits to their tolerance towards air pollutants (Kovacs, 1992; Cheng, 2003). Greening by plantation, which makes use of vegetation to remove, detoxify or stabilize persistent pollutants, is a green and environment friendly tool for clean environment. The screening of effective plants for particulate sink is very essential for air pollution abatement in urban environment. The routine analysis of elements thus needs from foliage of urban trees are essential to understand the level of metal bioaccumulation and its consequence effect on plant.

Increased urbanization, industrialization and heavy vehicular traffic have resulted in deterioration of air quality in the Esfahan city. However, no major attempt has been taken to asses about bioaccumulation of urban plant specifically to assess the tolerance of atmospheric pollutants in an appropriate manner. Hence, the present study is concerned with the establishment of air pollution biomonitoring capacity with special reference to biochemical and study in a critically polluted region of Iran.

MATERIALS AND METHODS

Study Area

The study was conducted in East of Esfahan city, Iran, located at 32°38′N and 51°29′E. This region is under arid and semiarid climate. The highest temperature recorded during this study was 45ºC during summer season, whereas lowest temperature recorded was 4ºC during autumn. The average annual rainfall recorded was 120 mm, mostly occurring during the winter season. The present study was conducted at two different sites one in Ghadir garden (Site 1) and another in highway (Site 2).

Sampling and Analysis

The leaves were collected from selected plant species like *Nerium oleander*, *Morus alba*, *Pyracantha* sp., *Olea europea*, *Ligustum* sp., *Fraxinus excelsior*, *Ulmus* sp., *Cercis siliquastrum* and *Berberis vulgaris* at a particular height of 0.5-2 meter from the ground from two sites (polluted site and control site). Nine plant species were selected during the spring and summer seasons of 2011. Samples were cleaned with distilled water and then refrigerated (22ºC) under suitable condition for further biochemical analysis. Various biochemical parameters such as leaf extracts pH (Sing and Rao, 1983), relative water content (Sen and Bhandari, 1978), total chlorophyll (Arnon, 1949), ascorbic acid (Keller and Schwager, 1977) were done from the collected leaf samples. The air pollution tolerance index was calculated using (Eq. 1):

$$APTI = \frac{A(T+P)+R}{10} \quad (1)$$

Where, A = Ascorbic acid content of leaf (mg g^{-1} of fresh weight)

T = Total chlorophyll of leaf (mg g^{-1} of fresh weight);

P = pH of leaf extract

R = relative water content, in percentage.

The method of Prusty *et al.* (2005) was used for collection and measurement of dust load in leaf surfaces. From each plant fully mature leaf samples from different heights were randomly collected and placed in a beaker and washed thoroughly by a hairbrush with distilled water. This water solution was then completely evaporated in an oven at 100°C and weighed with an electronic balance (Fartorious.CP-153) to record the total dust. The leaf area (cm^2) was recorded with a leaf area analyzer (AM200, ADS bioscientific LD).

The amount of dust was calculated following(Eq. 2):

$$W= (w_2-w_1) /n \quad (2)$$

Where, W = amount of dust (mg/cm^2),

w_1 = initial weight of beaker with dust,

w_2 = final weight of the beaker with dust,

n = total area of the leaf (cm^2).

RESULTS AND DISCUSSION

Biochemical Characterization of Leaf Extract

The biochemical characteristics of selected plants for the seasons of spring and summer are shown in the Tables 1 and 2 respectively. Ascorbic acid content in plant leaves shows variation from 0.15 to 0.80 mg/g in april, whereas in September, it varies 0.11 to 0.55 mg/g. The maximum content of ascorbic acid was found in *Cercis siliquastrum* (0.8) in the month of April and the lowest ascorbic acid content was observed in *Ulmus* sp. (0.01) in the month of September. In control site, the values are relatively higher than polluted site (maximum observed value is 0.9 mg/g). Resistant plants contain higher portion of ascorbic acid, while sensitive plants possess a lower level of it and the level declines with exposure to pollutant (Keller and Schwager, 1977). Thus, plants maintaining high ascorbic acid level even under polluted conditions are considered to be tolerant to air pollutants. The relative water content in plant leaves ranges from 52.2% to 97.8% with maximum in *Morus alba* (97.8%) in the month of April and lowest in *Cercis siliquastrum* (52.7%) in the month of September. Higher relative water content is reported to be advantageous for drought resistance (Dedio, 1975). Elevated levels of pH are observed in leaf extract of those plant species studied which shows the highest value for *Morus alba* (6.84) and lowest in *Berberis vulgaris* (3.29) in April. Overall pH was ranged from 3.29 to 6.84 and 3.82 to 7.77 in the months of April and September, respectively. However, most of the plants show pH in the range of 6 to 7. It is reported that, in the presence of an acidic pollutant, the leaf pH is reduced and the reducing rate is more in sensitive plants compare to that in tolerant plant species (Scholz and Reck, 1977). Thus level of pH in leaf extract of plants under polluted condition is strongly associated with their tolerance level to air pollutants. Total chlorophyll content (in mg/g of fresh weight) of the nine plant species examined exhibits elevated levels in most of the plants ranging from 1.06 to 5.14 mg/g in April whereas it ranges from 0.07 to 0.24 in September. Remarkable difference is observed in chlorophyll content between two seasons. *Ligustrum* sp. content of chlorophyll (5.14) in the month of April and lowest is observed in *Berberis vulgaris* (0.07) in the month of September. Chlorophyll is known as an important stress metabolites and higher chlorophyll content in plants might favour tolerance to pollutants (Joshi *et al.*, 1993).

Dust Deposition on Leaf Surface

Amount of dust deposition on leaf surfaces (g/m^2) was estimated and presented in Table 1 and 2 for the month of April and September respectively. Highest dust retaining capacity is found in *Morus alba* (41 g/m^2) in the month of April with the lowest in *Pyracantha* sp. (20.3 g/m^2) in the month of September. In general, deposited amount of dust ranged between 20.3 and 103 g/m^2 with higher deposition in September. The dust-filtering ability of the plant species was correlated with their foliar surface characteristics. The morphological characteristics which alone or in combination play a significant role in the interception of dust load from the ambience are: orientation of leaf on the main axis, size (leaf area in cm^2) and shape, surface nature (smooth/striate), the presence or absence of trichomes and wax deposition (Verma, 2003).

APTI Assessment

APTI value was calculated based on the biochemical parameters as described in methodology and variation of APTI among the plant species with respect to polluted site and control site in both seasons have been presented in Fig. 1 and 2. The highest APTI value was scored by *Morus alba* and *Berberis vulgaris* (10.2) in April, followed by *Cercis sliquastrum* (8.87), *Nerium oleander* (8.80), *Fraxinus excelsior* (8.36), *Pyracantha* sp. (7.89) *Olea europea* (7.84), *Ligustrum* sp. (6.70) and *Ulmus* sp. (6.14) respectively. The lowest APTI value was observed in *Cercis sliquastrum* (5.45) in September. Values of APTI varied from 5.45 to 9.69 in September whereas it varies 6.14 to 10.2 in April. In polluted site, APTI values are higher compared to control site particularly in month of April. In contrast, APTI values are lower in September, indicating the higher tolerance in this season. The APTI values obtained for different plants were compared to find out the sensitivity/tolerance of these plants. It was reported that plants with relatively low index value are generally sensitive to air pollutants and vice versa (Singh *et al*., 1991). The APTI determination provides a reliable method for screening large number of plants with respect to their susceptibility to air pollutants. The method is simple and convenient to adopt under field conditions without adopting any costly environmental monitoring gadgets. Among the six plant species studied *Morus alba* was considered as relatively resistant and *Cercis sliquastrum* as relatively sensitive to air pollution. The sensitive species can be used as bio-indicators and tolerant species can be used as a sink for air pollutants. Plants have been categorized into groups according to their degree of sensitivity toward and tolerance of various air pollutants on the basis of experiment and available data (Khan and Abbasi, 2002). Levels of tolerance to air pollution vary from species to species, depending on the capacity of plants to withstand the effect of pollutants without showing any external damage.

CONCLUSION

The use of vegetation samples as bioindicators of the degree of pollution through biochemical study in environmental monitoring is well known. In this study all the plant species showed considerable variation among the biochemical parameters like pH, ascorbic acid, relative water content, and chlorophyll content. *Morus alba* exhibited higher chlorophyll level compared to other species. The biochemical analysis, although not producing clear trends, will help in identifying pollution sources. Their magnitude was seemed to depend strongly as a function of the atmospheric availability of pollutants. The application of APTI techniques for tolerance species identification in vegetative samples has also another importance for emerging alternative method. This kind of biomonitoring study therefore provides the information of the greater level of atmospheric pollution load in urban region.

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Tables

Table 1. Results of the biochemical analysis of tree leaves (Nine different species) from polluted site and control site in April, 2011

Scientific Name	pH	Ascorbic Acid (mg/g F.W)	Total Chlorophyll (mg/g FW)	Relative water content (%)	Dust deposition (g/m²)
			Control site		
Nerium oleander	6.42	0.11	6.70	79.6	11.5
Morus alba	7.47	0.90	13.9	93	32.3
Pyracantha sp.	4.97	0.11	7.54	95.3	13.2
Olea europea	5.76	0.62	0.59	70.1	9.5
Ligustrum sp.	5.81	0.19	1.26	62.5	7.9
Fraxinus excelsior	7.02	0.22	3.06	67.4	16.
Ulmus sp.	6.31	0.15	7.27	57.5	20.5
Cercis sliquastrum	4.51	0.74	1.92	84.2	2.9
Berberis vulgaris	3.19	0.58	3.27	87.8	15.5
			Polluted site		
Nerium oleander	6.64	0.15	1.46	86.8	20.5
Morus alba	6.84	0.415	2.17	97.9	41
Pyracantha sp.	6.61	0.19	1.26	77.4	36.4
Olea europea	5.70	0.55	1.06	74.7	10
Ligustrum sp.	5.92	0.27	5.14	64.1	23
Fraxinus excelsior	5.52	0.55	3.07	78.8	20.5
Ulmus sp.	6.64	0.26	2.25	59.1	29.8
Cercis sliquastrum	6.31	0.80	2.03	81.9	15.5
Berberis vulgaris	3.29	0.37	1.67	52.2	16.7

Table 2. Results of the biochemical analysis of tree leaves (Nine different species) from polluted site and control site in September, 2011

Scientific Name	pH	Ascorbic Acid (mg/g F.W)	Total Chlorophyll (mg/g FW)	Relative water content (%)	Dust deposition (g/m²)
			Control site		
Nerium oleander	7.16	0.09	0.30	80.9	12.9
Morus alba	7.44	0.60	0.41	98.4	47.3
Pyracantha sp.	6.56	0.20	0.29	71.3	16.5
Olea europea	6.78	0.37	0.05	95.1	27
Ligustrum sp.	6.5	0.38	0.29	99.0	35.8
Fraxinus excelsior	6.17	0.43	0.09	66.1	102.7
Ulmus sp.	6.32	0.43	0.24	71.4	41.7
Cercis sliquastrum	6.46	0.54	0.27	98.1	13.5
Berberis vulgaris	3.53	0.10	0.16	90.4	37.7
			Polluted site		
Nerium oleander	7.07	0.23	0.07	73.8	55.5
Morus alba	7.77	0.55	0.24	71.3	53
Pyracantha sp.	6.27	0.25	0.12	80.2	20.3
Olea europea	6.31	0.11	0.08	87.4	55.2
Ligustrum sp.	5.8	0.55	0.13	87.9	49.2
Fraxinus excelsior	6.99	0.50	0.11	93.3	103.2
Ulmus sp.	6.68	0.01	0.23	76.3	48.5
Cercis sliquastrum	6.54	0.26	0.12	52.8	36.7
Berberis vulgaris	3.82	0.09	0.07	80.5	64.7

Figures

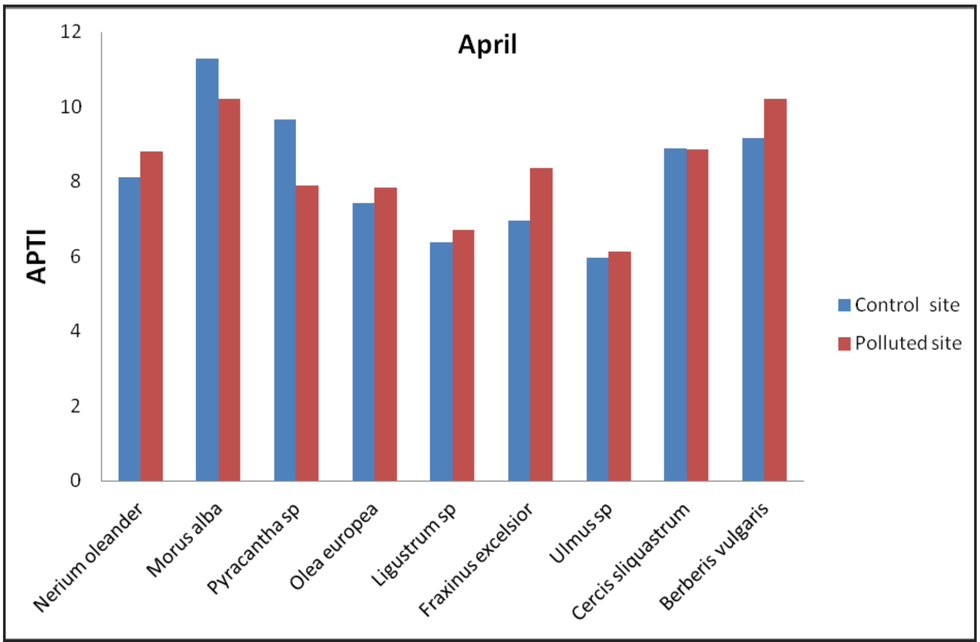

Fig. 1. Variation of APTI among the plant species under study with respect to polluted site and control site in April, 2011

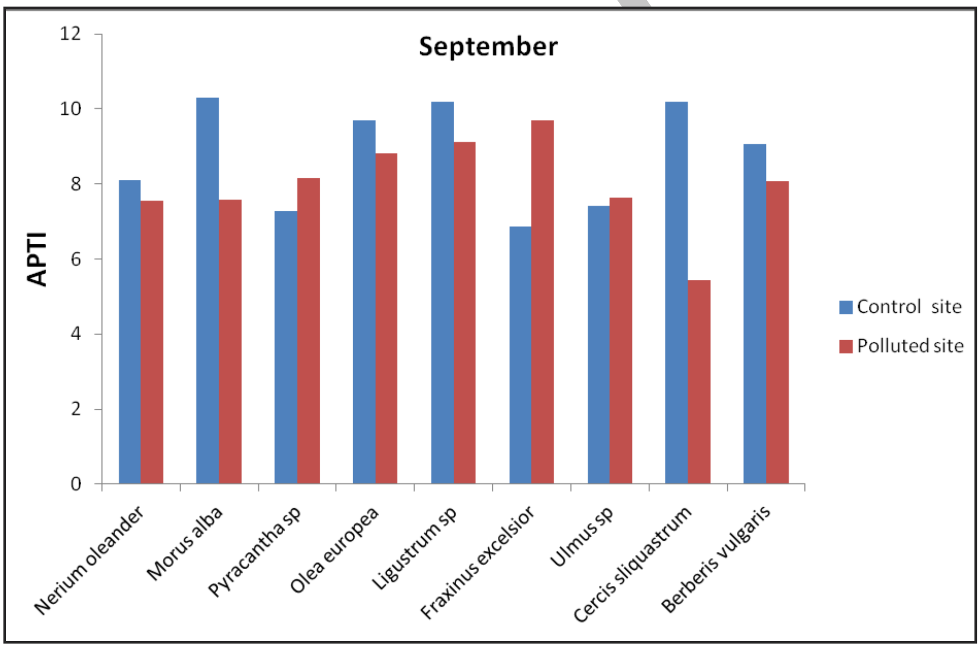

Fig. 2. Variation of APTI among the plant species under study with respect to polluted site and control site in September, 2011