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Foliar Biochemical Features of Plants As Indicators of Air Pollution

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Cities in developing nations are being industrialized and increasing rapidly in size and diversity. It is accompanied by increasing emissions from vehicular traffic, industry, domestic heating, cooking and refuse burning which pose potential health risk for large scale air pollution exposure. The rapidity of economic development combined with lack of emission controls, makes megacities prone to more serious air pollution problems than similar cities in industrial nations (WHO/UNEP 1992 ; CPCB 1995). However, plants play an important role in maintaining the ecological balance by actively participating in the cycling of nutrients and gases like carbon dioxide, oxygen and air pollutants. Sensitivity and responses of plants to air pollutants is variable. Some plants are more sensitive and act as biological indicators of air pollution (Kozhouharov *et al.*1985; Guderian *et al.* 1998). Others, which are tolerant, may act as sink to air pollutants. However, this aspects needs more investigation for their use as indicators of air pollution and in abatement of air pollution. Effect of air pollution on plants have long been known (Bobrov 1955, Solberg and Adams 1950). Various changes induced by air pollutants in plants with respect to morphological and anatomical (Sharma 1977; Yunus et al. 1979; Garg and Varshney 1980; Mishra 1982), physiólogical (Dugger et al. 1962; Lee 1965; Crittenden and Read 1979) and biochemical (Cracker 1972; Tringey and Reinert 1975; Malhotra and Hocking 1976) characteristics have been recorded. However, the study carried out till now is inadequate considering the vast diversity of plants and different responses shown by them.

The present study was undertaken to study the foliar traits in the commonly occurring plants of Nagpur, India, from urban, industrial and non-polluted area. Observations were made on the anatomy and biochemical makeup of plant species to facilitate comparison with reasonable validity to the generalizations made based on this data. The data on the ambient air quality status and climatic features during the study period was also collected, to study their impact on the biochemical foliar traits of the plants.

MATERIALS AND METHODS

Nagpur is an important center of industry, education and agriculture in Vidarbha Region of Maharashtra State in India. The city is situated between $20^0.30'$ and '21^0 30' N latitude and $78^0.30'$ and $79^0.30'$ E longitude. The strategic situation of this city in the central part of India has led to rapid expansion of city and ever-increasing environmental problems especially with reference to pollution of air, water and soil. Three sampling stations were selected within the city to assess the impact of air pollution on plants. These sampling stations are 1) Seminary Hills (SH) (control unpolluted area) 2) Itwari (IT) (crowded commercial/residential area with automobile and dust pollution) and, 3) Maharashtra Industrial Development Corporation (MIDC)

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Area (automobiles and industrial gaseous discharge). Ambient air quality monitoring for suspended particulate matter (SPM), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) was carried out twice in a month, round the clock each time, during the study period from August to December 1996 which is the peak period of occurrence of air pollutants in the atmosphere. Gaseous pollutants viz. SO_2 and NO_2 were collected on eight hourly basis by drawing air at a flow rate of 0.5 lit/min through a solution of potassium tetrachloromercurate (TCM) and sodium hydroxide absorbing media respectively. The nitrite ions produced during the sampling is reacted with phosphoric acid, sulphonilamide and NEDA to form an azo dye. The concentration of NO_2 is determined colorimetrically at wavelength 550 nm. In case of SO_2, the TCM complex is reacted with pararosaniline and formaldehyde to form intensely coloured pararosaniline methyl sulphonic acid. The absorbance of the solution is measured spectrophotometrically at wavelength 560 nm. SPM was collected at 24 hourly basis by drawing air at a flow rate of 1.5 m^3/min through glass fibre filter paper using High Volume Sampler. Standard methods used for quantification of pollutants were given elsewhere (Katz 1977). The data on weather parameters viz. temperature, relative humidity, rainfall and sky clearance was collected from Meteorological Department for the study period. The plants namely *Bougainvillaea spectabilis, Azadirachta indica, Pongamia pinnata* and *Polyalthia longifolia* growing in these areas were selected for studying the impact of air pollution. The leaf samples were analyzed for pH (P) of leaf extract (Singh and Rao 1993), Chlorophyll (T) (Arnon 1949), Ascorbic acid (A) (Singh 1977), and Relative Water Content (R). Air pollution Tolerance Index (APTI) which gives an empirical value representing tolerance level of a plant to air pollution was used to interpret the impact of pollution on the plants (Singh and Rao 1983). APTI is calculated by the formula as A(T+P) + R/10.

RESULTS AND DISCUSSION

Fortnightly averages of atmospheric temperature and relative humidity, total rainfall and sky clearance days are shown in Table 1. Minimum temperature was highest in August viz. 81^0 F and showed gradual decrease upto December viz. 52.6^0 F. Maximum temperature gradually increased from 85^0 F to 91.8^0 F from August to September and then showed gradual reduction to 77.7^0 F in December. Peak in relative humidity (both min. and max.) was in August i.e. 71.1% and 94.4% respectively and showed gradual decrease upto December i.e. 24.2% and 66.3% respectively. Rainy days were maximum i.e. 23 and 13 in August and September respectively, followed by 8 in October, 1 in November and Nil in December. The monthly maximum precipitation i.e. 127.8 mm and 194.9 mm was recorded in August and September respectively and less in October i.e. 148.9 mm and almost negligible in November and December. The year 1996 experienced a deficient rainfall in the Nagpur City. A total of 857mm rainfall was received during rainy season, which was deficient as compared to average annual rainfall of 1000 to 1300 mm. The deficient rainfall resulted in more extreme variations in temperature and relative humidity and more acute problems of dust and gaseous pollution. Extreme temperature variations in 1996 were evident from the fact that the difference between minimum and maximum temperature that was 4 to 12.8 in August, became 24.9 to 36.2 in December 1996. This year the days with temperature lower than 8^0C were more in November and December as compared to previous years. Similarly, relative humidity reduced considerably at the end of December month.

Ambient air quality data from August to December 1996 is presented in Table 2. Month-wise average values of SPM ranged from 43-160 $\mu g/m^3$, 108-276 $\mu g/m^3$ and 59-186 $\mu g/m^3$ at Seminary Hill, Itwari and MIDC area respectively. Highest concentration i.e. 276 $\mu g/m^3$ was recorded in November in Itwari area. Concentration

Table 1. Meteorological data for Nagpur City (Average values of fifteen days data)

Sr. No.	Month	Temperature		Relative Humidity (%)		Total Rainfall (mm)	Remark
		Min	Max	Min	Max		
1	August A.	81.0	85.0	66.9	91.3	51.2	Rainy day-9 Partly cloudy sky
	B.	74.7	87.5	71.1	94.4	176.6	Rainy days – 14 Mostly cloudy sky
2	September A.	74.4	84.2	64.6	92.7	59.6	Rainy days – 4 Mostly cloudy sky
	B.	73.7	91.8	52.5	89.7	135.3	Rainy days – 9 Mostly cloudy sky
3	October A.	69.2	90.2	42.4	83.4	13.6	Rainy days – 4 Mainly clear sky
	B.	73.7	91.8	52.5	89.7	135.3	Rainy days – 4 Mainly clear sky
4	November A.	64.8	88.7	32.2	67.1	25.1	Rainy days – 1 Mainly clear sky
	B.	57.4	82.2	28.0	78.1	---	Rainy days –Nil Mainly clear sky
5	December A.	52.8	77.7	37.4	67.9	---	Rainy days – Nil Mainly clear sky
	B.	52.6	88.8	24.2	66.3	---	Rainy days – Nil Mainly clear sky

A : First fortnight of the month; B : Second fortnight of the month.

of NO_2 in air ranged from 4-12 $\mu g/m^3$, 7-17 $\mu g/m^3$ and 5-16 $\mu g/m^3$ at Seminary Hill, Itwari and MIDC area respectively. Highest concentration of NO_2 i.e. 17 $\mu g/m^3$ was recorded in November and December at Itwari. Levels of SO_2 in air ranged form 6-10 $\mu g/m^3$, 6-19 $\mu g/m^3$ and 6-19 $\mu g/m^3$ at Seminary Hill, Itwari and MIDC area respectively.

Table 2. Ambient air quality of Nagpur City

Month	SPM ($\mu g/m^3$)			SO_2 ($\mu g/m^3$)			NO_2 ($\mu g/m^3$)		
	MIDC	Itwari	Semi-nary Hill	MIDC	Itwari	Semi-nary Hill	MIDC	Itwari	Semi-nary Hill
Aug.	59	108	43	6	6	6	5	7	4
Sep.	63	145	72	6	6	6	7	10	5
Oct.	160	185	104	9	13	6	10	14	8
Nov.	186	276	145	15	17	7	14	17	10
Dec.	172	203	160	19	19	10	16	17	12

Highest concentration of SO_2 i.e. 19 $\mu g/m^3$ was recorded in December at MIDC and Itwari area. Density of air pollutants fluctuated according to seasonal changes in climatic features. In rainy season, the air pollutants were least in concentration due to wash out by precipitation (Table 1). However, the concentration of pollutants

considerably increased in October, November and December. Higher values of SPM were attributed to intense human activity and on the other hand to annual less precipitation in 1996. The control area (SH) showed lower levels of air pollutants as compared to those in polluted MIDC and Itwari Area. Though the values of SO_2 and NO_2 in control area (SH) are well below the standards, SPM values exceed the standards for sensitive area i.e. 100 $\mu g/m^3$. The levels of air pollutants in the polluted study areas, Itwari and MIDC, were considerably greater than those at control Seminary Hill area. SPM was found to be 1.3 to 2.5 times greater, SO_2 1.8 to 2.4 times greater, and NO_2 1.4 to 2.0 times greater than their baseline values in the control Seminary Hill area. The residential Itwari area showed the values of pollutants SO_2 and NO_2 well below the National Ambient Air Quality Standards (NAAQS) values, and the values of SPM above NAAQS values of 200 $\mu g/m^3$. In MIDC area, the values of all the pollutants are below the NAAQS, though it shows higher levels of these pollutants than the baseline concentration in the control area. Thus the ambient air quality is satisfactory in Nagpur. However, the rapid expansion of city, increasing number of automobiles and proposed big industrial area near the Nagpur indicate that Nagpur would also be classified as polluted city if preventive environmental management measures are not undertaken. The foregoing discussion shows that present level of pollutants are lower than the prescribed limits except SPM. However these chronic levels are prevailing for a long time i.e. more than 20 years. It is the vegetation cover that is acting as sinks to the air pollutants and playing important role in keeping the levels of pollution well below the standards. Nagpur is a green city. Efforts of many social organizations, private institutions and Government agencies have implemented a plantation drive in the city for the last 15-20 years. Many forest patches are developed along the hilly area, many gardens have been well maintained in different parts of the city.

However the vegetation cover is relatively less in the old Nagpur City viz. Itwari where the residents of that area feel the impact of air pollution. The vegetation of Nagpur City is exposed to dust pollution and chronic concentration of gaseous pollutants, which may affect the biochemical make up, and tolerance capability of plants to the air pollution. Biochemical characteristics of leaves and Air Pollution Tolerance Index (APTI) for the plants from SH, IT and MIDC are shown in Table 3, 4 and 5 respectively. Total Chlorophyll content (mg/gm dry wt) in the leaves *of Azadirachta, Pongamia, Bougainvillaea* and *Polyalthia* from SH was 2.978, 1.749, 3.736 and 4.313 respectively. Chlorophyll content in the leaves decreased in Itwari area (except increase in *Pongamia*) and increased in MIDC area. Relative Water Content (%) of leaves of these plants from SH varied from 82.78 to 93.39. It did not show any particular trend in the plants from polluted area. It was found to be marginally increased in Itwari area while increased / reduced in MIDC area. Ascorbic acid content (mg/gm by dry wt) was found to vary in the leaves of all plants at SH from 5.38 to 54.00. The ascorbic acid content increased, in general in the leaves of plants at IT and MIDC. Highest increase was found in *Pongamia* and *Bougainvillea* species. The APTI of the plants from SH ranged from 13.09 to 61.39, the maximum being in case of *Azadirachta* species. APTI values, in general, showed increase in case of plants from polluted region. APTI values ranged from 16.69 to 31.44 for plants from IT and 22.02 to 83.15 for plants from MIDC. APTI values of the four common trees in polluted areas were found to vary from 13.09 to 83.15 and the plants are listed according to their tolerance or sensitivity to pollution (Table 6). Raza et al. (1985) also found a range of 13.03 to 138 while studying the APTI index of 39 species of trees, shrubs and herbs form Nizam College Campus, Hyderabad. Higher values of APTI indicates the tolerance of the plants to air pollutants (Smith andBochinger 1975). *Azadirachta indica* was found to be the most tolerant species in

the environment of Nagpur. Its APTI values are 61.36 in control area of Seminary Hills, 31.44 in Itwari and 83.15 in MIDC. This tree is highly suitable for plantation in residential and industrial areas. This species is observed to have APTI of 27 at Hyderabad (Raza et. al.1985). The same author states that a plant species known to be sensitive or tolerant in one geographical area may behave differently in another area. Next to *Azadirachta* sp., *Bougainvillaea* sp. was found to have APTI Index values of 16.87 at Seminary Hill, 27.44 at Itwari and 27.83 in MIDC area. *Polyalthia* sp, which ranks next showed APTI values of 18.40 at Seminary Hills and 21.64 and 22.12 at Itwari and MIDC respectively. *Pongamia* sp. showed APTI values of 13.09, 16.96 and 22.54 at seminary Hills, Itwari and MIDC area respectively. Though these species

Table 3. Biochemical characteristics of the leaves and air pollution tolerance index (APTI) of selected plants from Seminary Hill area

Sr. No.	Name of Plant Species	Total Chloroph-yll (mg/gm dry weight)	Relative Water Content (%)	Ascorbic Acid Content (mg/gm dry weight)	pH	APTI Value
1	*Azadirachta indica*, A. Juss.	2.978	83.80	54.00	6.8	61.36
2	*Pongamia pinnata*, Pierre	1.749	84.79	5.38	6.9	13.09
3	*Bougainvillaea spectabilies*, Willd	3.736	82.78	8.11	6.7	16.87
4	*Polyalthia longifolia*, *v. pendula* Bentham and Hooker	4.313	93.39	8.37	6.5	18.40

showed different sensitivity, they all appear to be tolerant to air pollution as their APTI values showed increase, in general, in polluted environment. There was considerable increase in the ascorbic acid content of the leaves of these plant species in polluted environment. Ascorbic acid content is known to improve the tolerance of the plants to air pollutants. It is because of this parameter, APTI values of plants showed increase in polluted environment. This may probably be the reason that the plant develop tolerance and detoxify the absorbed pollutants, and as a result other biochemical constituents are not affected in such plants. Chlorophyll content of the leaves showed increase in the polluted environment except in case of Polyalthia sp. growing in Itwari area. Relative water content was not found to follow any specific trend in unpolluted and polluted environment. The pH of the leaf became more alkaline in the plants of polluted environment. This can be taken as an indication of the development of detoxification mechanism in the plant necessary for the tolerance. Chlorophyll content of the plant was observed to be decreased, in general, at Itwari area. This must have been due to deposition of more dust over leaf surface in Itwari area. Higher dust levels are known to cause damages by producing necrosis and leaf discolouration.

Present work has indicated the suitability of *Azadirachta indica* A. Juss as the most tolerant species and suitable sink for air pollution. It can be utilized for urban plantation and green belt development in industrial areas to reduce the level of air pollution. It is also observed that the biochemical traits of all the four species are valuable sensitive indicators of air pollution. However, more research is necessary on a wide variety of trees, shrubs and herbs to prepare a biological sensitivity map of flora. The vast

Table 4. Biochemical characteristics of the leaves and air pollution tolerance index (APTI) of selected plants from Itwari area

Sr. No.	Name of Plant Species	Total Chlorophyll (mg/gm dry weight)	Relative Water Content (%)	Ascorbic Acid Content (mg/gm dry weight)	pH	APTI Value
1	*Azadirachta indica*, A. Juss.	2.505	85.03	25.15	6.74	31.4
2	*Pongamia pinnata*, Pierre	2.889	84.23	8.85	7.07	16.9
3	*Bougainvillaea spectabilies*, Willd	3.446	86.87	17.20	7.37	27.2
4	*Polyalthia longifolia, v. pendula* Bentham and Hooker.	1.746	93.49	14.93	6.65	21.6

Table 5. Biochemical characteristics of the leaves and air pollution tolerance index (APTI) of selected plants from MIDC area

Sr. No.	Name of Plant Species	Total Chlorophyll (mg/gm dry weight)	Relative Water Content (%)	Ascorbic Acid Content (mg/gm dry weight)	pH	APTI Value
1	*Azadirachta indica*, A. Juss.	3.943	82.98	69.37	6.86	83.1
2	*Pongamia pinnata*, Pierre	2.859	90.87	14.31	6.77	22.5
3	*Bougainvillaea spectabilies*, Willd	4.574	86.61	16.26	7.32	27.8
4	*Polyalthia longifolia, v. pendula* Bentham and Hooker.	4.442	91.06	11.91	6.48	22.0

Table 6. Arrangement of tree species according to their tolerance to air pollution in different areas of Nagpur City

Sr. No.	Name of the Plants and their APTI Values		
	Seminary Hill	Itwari	MIDC
1	*Azadirachta* (61.36)	*Azadirachta* (31.44)	*Azadirachta* (83.15)
2	*Polyalthia* (18.40)	*Bougainvillaea* (27.44)	*Bougainvillaea* (27.83)
3	*Bougainvillaea* (16.87)	*Polyalthia* (21.64)	*Pongamia* (22.54)
4	*Pongamia* (13.09)	*Pongamia* (16.96)	*Polyalthia* (22.12)

database would be useful in identifying tolerant plants, sink plants and indicator species for effective air pollution management programme.

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