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Air pollution tolerance index of selected roadside plant species in Aizawl, Mizoram, India

AIR pollution tolerance index (APTI) indicates the capability of plant species to mitigate air pollution. Plants purify the air by intercepting particulate matter and smoke, acting as a scavenger for pollutants. The plants sensitive to pollutants act as a pollution bio-indicator. APTI can be helpful in developing appropriate management strategies using plants to minimize the level of air pollutants. The studies on the plant responses to a particular pollutant and APTI based on biochemical parameters are paramount[1,2]. The ability of leaves to intercept dust particles depends on their water holding capacity, chlorophyll content, leaf ascorbic acid content, tree height and canopy[3].

There is ample scope to study plant–pollutant interactions and the absorption of pollutants by plants. Primary pollutants such as sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and suspended particulate matter (SPM) enter the plants through stomatal apertures during gaseous exchanges. In the leaves, NO_2 forms nitrous acid which converts ammonia to amino acids and further to proteins[4]. Extensive research has been conducted globally on APTI[1,5–27]. However, there is a paucity of information in Mizoram, North East India. Hence, the present study has been carried out during 2020–21 with an aim to assess the APTI.

Three study sites were selected in the capital of Aizawl in Mizoram. Site-1 (between Sikulpuikawn and Bawngkawn) with heavy traffic, site-2 (New Capital Complex to Khatla) with medium traffic and site-3 (Lalsavunga Park area to Hlimen) with low traffic density. *Mangifera indica*, *Ficus religiosa*, *Ficus benjamina* and *Artocarpus heterophyllus* common at all sites were selected and fully mature leaves were collected in replicates on a seasonal basis for analysis of relative water content[28], pH, ascorbic acid[29], and chlorophyll content[30]. Finally, APTI was calculated using the following formula[31]:

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

where A is the ascorbic acid content (mg/g), T the total chlorophyll content (mg/g), P the pH of leaf extract and R is the relative water content of leaves (%). The plant species were classified as sensitive, tolerant, intermediate and moderately tolerant according to APTI values[9].

Irrespective of the season, there was an increasing trend in relative leaf water content (RWC) from *F. religiosa* to *A. heterophyllus*, *F. benjamina* and *M. indica*, and higher values were reported during monsoon season at all sites. RWC (%) ranged between 51.26 (*F. benjamina* at site-3 in pre-monsoon) and 90.23 (*M. indica* at site-1 in post-monsoon) (Table 1). RWC of trees is the capacity of the leaves to hold water that helps in physiological balance under the stress of air pollution[9,31]. Plants having high RWC denote a high level of tolerance to pollutants[32]. During all the seasons, there was an increasing trend in pH of leaf extract from *F. benjamina*, *A. heterophyllus*, *F. religiosa* and *M. indica*. pH was always in the alkaline range for *M. indica* and acidic for *A. heterophyllus* and *F. benjamina*. The pH value ranged between 5.7 (*F. benjamina* at site-3 in pre-monsoon) and 7.6 (*M. indica* at site-1 in post-monsoon) (Table 2). The decline in leaf pH could be due to decreasing efficiency for converting hexose sugar to ascorbic acid[31,32]. Total chlorophyll content was higher for *M. indica* followed by *A. heterophyllus*, *F. benjamina* and *F. religiosa*. The total chlorophyll content varied between 0.38 (*M. indica* at site-1 in monsoon) and 2.56 (at site-3 in pre-monsoon) (Table 3). Chlorophyll in plants shows photosynthetic activity, growth, accumulation of biomass and health[18,32,33].

The highest value of ascorbic acid (AA) content was reported in *F. benjamina* followed by *F. religiosa*, *M. indica* and *A. heterophyllus* during all seasons and at all sites. The range of AA varied from 0.02 (*A. heterophyllus* at site-1 in pre-monsoon)

Table 1. Relative water content (RWC) of leaves for selected tree species

	RWC (%)								
	Pre-monsoon season			Monsoon season			Post-monsoon season		
Tree species	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
Mangifera indica	87.31 ± 2.58	86.54 ± 1.95	84.63 ± 2.15	90.23 ± 2.21	88.65 ± 2.56	88.04 ± 2.18	88.27 ± 2.26	87.96 ± 2.24	87.17 ± 1.97
Ficus religiosa	52.36 ± 1.82	51.26 ± 1.65	51.56 ± 1.95	60.48 ± 1.88	55.74 ± 2.15	53.56 ± 1.95	58.23 ± 1.63	53.86 ± 2.10	52.56 ± 2.14
Ficus benjamina	68.65 ± 2.15	66.24 ± 2.24	65.85 ± 2.44	71.67 ± 2.41	70.22 ± 1.56	70.45 ± 2.11	70.56 ± 1.96	68.65 ± 1.89	67.32 ± 1.76
Artocarpus heterophyllus	61.23 ± 2.58	61.23 ± 2.12	60.45 ± 1.98	65.54 ± 2.65	64.84 ± 1.97	64.47 ± 1.87	63.21 ± 1.88	62.24 ± 1.66	62.14 ± 2.19

±, Standard error.

Table 2. pH of leaf extract for selected tree species

	pH of leaf extract								
	Pre-monsoon season			Monsoon season			Post-monsoon season		
Tree species	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
Mangifera indica	7.7 ± 0.13	7.5 ± 0.23	7.7 ± 0.24	7.2 ± 0.44	7.3 ± 0.23	7.5 ± 0.25	7.6 ± 0.18	7.1 ± 0.31	7.5 ± 0.06
Ficus religiosa	6.8 ± 0.24	6.9 ± 0.18	6.8 ± 0.15	7.1 ± 0.17	7.2 ± 0.15	7.1 ± 0.16	6.9 ± 0.23	6.9 ± 0.24	7.1 ± 0.14
Ficus benjamina	5.8 ± 0.28	6.1 ± 0.22	5.7 ± 0.31	6.2 ± 0.54	6.5 ± 0.32	6.2 ± 0.27	6.2 ± 0.21	6.3 ± 0.11	6.2 ± 0.21
Artocarpus heterophyllus	6.2 ± 0.17	6.2 ± 0.15	6.3 ± 0.17	6.8 ± 0.31	6.9 ± 0.14	6.3 ± 0.21	6.5 ± 0.17	6.5 ± 0.19	6.4 ± 0.17

±, Standard error.

Table 3. Chlorophyll content of leaves for selected tree species

	Chlorophyll content (mg/l)								
	Pre-monsoon season			Monsoon season			Post-monsoon season		
Tree species	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
Mangifera indica	2.34 ± 0.01	1.98 ± 0.02	1.59 ± 0.03	2.56 ± 0.12	2.03 ± 0.18	1.95 ± 0.21	2.36 ± 0.14	2.08 ± 0.17	1.88 ± 0.12
Ficus religiosa	0.48 ± 0.03	0.42 ± 0.02	0.38 ± 0.02	0.51 ± 0.08	0.52 ± 0.06	0.48 ± 0.09	0.51 ± 0.06	0.49 ± 0.04	0.45 ± 0.07
Ficus benjamina	0.53 ± 0.02	0.49 ± 0.03	0.44 ± 0.01	0.68 ± 0.06	0.56 ± 0.09	0.52 ± 0.07	0.64 ± 0.09	0.54 ± 0.09	0.49 ± 0.03
Artocarpus heterophyllus	2.12 ± 0.01	1.75 ± 0.01	0.85 ± 0.02	2.24 ± 0.14	1.96 ± 0.14	1.44 ± 0.17	2.14 ± 0.17	1.92 ± 0.14	1.21 ± 0.16

±, Standard error.

Table 4. Ascorbic acid content of leaves for selected tree species

	Ascorbic acid content (mg/l)								
	Pre-monsoon season			Monsoon season			Post-monsoon season		
Tree species	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
Mangifera indica	0.12 ± 0.02	0.18 ± 0.04	0.05 ± 0.07	0.21 ± 0.04	0.11 ± 0.09	0.07 ± 0.06	0.19 ± 0.06	0.12 ± 0.07	0.07 ± 0.06
Ficus religiosa	0.24 ± 0.01	0.19 ± 0.03	0.18 ± 0.09	0.26 ± 0.03	0.21 ± 0.04	0.2 ± 0.04	0.26 ± 0.04	0.21 ± 0.05	0.19 ± 0.02
Ficus benjamina	0.28 ± 0.02	0.21 ± 0.04	0.18 ± 0.04	0.35 ± 0.09	0.2 ± 0.05	0.31 ± 0.09	0.29 ± 0.08	0.19 ± 0.08	0.29 ± 0.07
Artocarpus heterophyllus	0.02 ± 0.03	0.04 ± 0.05	0.03 ± 0.12	0.12 ± 0.18	0.06 ± 0.07	0.04 ± 0.03	0.11 ± 0.05	0.08 ± 0.04	0.04 ± 0.05

±, Standard error.

Table 5. Air pollution tolerance index (APTI) values of selected tree species

Tree species	APTI value								
	Pre-monsoon season			Monsoon season			Post-monsoon season		
	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3	Site-1	Site-2	Site-3
Mangifera indica	9.93	9.41	8.92	11.07	9.89	9.46	10.71	9.89	9.37
Ficus religiosa	6.98	6.51	6.44	8.02	7.19	6.87	7.74	6.93	6.69
Ficus benjamina	8.63	8	7.69	9.57	8.43	9.12	9.03	8.16	8.67
Artocarpus heterophyllus	6.28	6.44	6.25	7.63	7.01	6.75	7.27	6.89	6.51

±, Standard error.

to 0.35 (*F. benjamina* at site-1 in monsoon) (Table 4). A higher concentration of AA in leaves indicates exposure to high concentration of SO_2, and shows higher tolerance. Higher AA in *M. indica* has also been reported in other studies[32]. It is a reducing agent which transforms SO_2 to SO_3. It helps trees protect the thylakoid structure and chlorophyll from reactive oxygen species[34]. The APTI values of selected trees ranged between 6.25 (*A. heterophyllus* at site-3 in pre-monsoon) and 11.07 (*M. indica* at site-1 in monsoon), with minimum and maximum values for *A. heterophyllus* and *M. indica* at all the sites irrespective of the season (Table 5). Singh and Rao[31] used similar variables as in the present study for the evaluation of APTI and reported that a combination of multiple parameters gives reliable results compared to a single biochemical parameter. Higher APTI values are indicative of increased pollution stress. Seasonal APTI variability was also reported for plant species[33]. Thus, it may be concluded that *M. indica* having the highest APTI value is the most tolerant species, while *A. heterophyllus* having the lowest APTI value could be categorized as pollution-sensitive.

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