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ASSESSMENT OF AIR POLLUTION TOLERANCE INDICES FOR CERTAIN ROADSIDE PLANTS IN AIZAWL, MIZORAM, INDIA

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ABSTRACT

The present study, evaluates five common plant species grown along the roadside of Aizawl by calculating the air pollution tolerance index (APTI) which is based on their significant biochemical parameters such as total chlorophyll, ascorbic acid, pH of leaf extract and relative water content. Among the plant species studied, *Artocarpus heterophyllus* with high APTI value (9.3) to be termed as tolerant among other species whereas plants species such as *Lagerstroemia speciosa* showed lowest APTI value (6.6) was termed as sensitive plant and to be treated as bio indicator of pollution. Anticipated Performance Index (API) value, incorporating APTI, physiognomy as well as some socioeconomic parameters, was also calculated for these plant species. According to API, *Artocarpus heterophyllus* (75%) proved to be fairly good performer whereas *Psidium guajava* (56.25%) and *Hibiscus rosa sinensis* (56.25%) were suggested as moderately suitable for green belt plantation.There was significant negative and positive correlation between air pollutants and biochemical parameters. Selection of appropriate bio-indicators as well as tolerant species is extremely relevant in the field of air pollution science.

KEY WORDS
APTI
Bio indicator
Chlorophyll
Ascorbic acid
Relative water content

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INTRODUCTION

The increased level of industrialization along with an unplanned urbanization witnessed with an enhanced level of air pollution. The plant bodies greatly influenced with these air pollutants by adsorbing, absorbing, accumulating or even by integrating it (Shannigrahi *et al*., 2003). Air pollution control seems very complex, no physical or chemical method is known to ameliorate the aerial pollutant. A suitable alternative may be to develop a biological method by growing plant in and around industrial and urban areas (Agarwal, 1988; Santra, 1995; Thakre, 1995; Sivasamy and Srinivasan, 1996; Fukuoka, 1997; Ghose and Majee, 2001; Shannigrahi *et al*., 2003; Prajapati and Tripathi, 2008; Mondal *et al*., 2011; Pathak *et al*., 2011; Rai, 2011a; Rai, 2011b; Rai, 2013). Plants act as a sink or even as living filters to minimize air pollutant by developing characteristic response and symptoms. Moreover, roadside plant leaves are in direct contact with air pollutant, and may act as stressors for these pollutants, hence to be examined for their biomonitoring potential (Pandey *et al*., 2005; Sharma *et al*., 2007; Rai, 2011a; Rai, 2011b.). Moreover, the biomonitoring of plants is an important tool to evaluate the impact of air pollution (Rai, 2011a; Rai, 2011b). The ability of each plant species to absorb and adsorb pollutants by their foliar surface varies greatly and depends on several biochemical, physiological and morphological characteristics (Singh and Verma, 2007; Kulshreshtha *et al*., 2009; Seyyednjad *et al*., 2011). Much experimental work has been conducted on the analysis of air pollution effects on crops and vegetation at various levels ranging from biochemical to ecosystem levels (Tiwari *et al*, 2006; Seyyednejad and Koochak., 2011).Plants that are constantly exposed to environment pollutants absorb, accumulate and integrate these pollutants into their system and depending on their sensitivity level, they show visible changes including alteration in the biochemical processes or accumulation of certain metabolites (Agbaire and Esiefarienrhe,2009) . Pollutants can cause leaf injury, stomatal damage, premature senescence, decrease photosynthetic activity, disturb membrane permeability and reduce growth and yield in sensitive plant species (Tiwari *et al*, 2006; Horaginamani and Ravichandran, 2010). The variation in the biochemical parameters in the leaves was used as an indicator of air pollution for early diagnosis of stress or as a marker for physiological damage prior to the onset of visible injury symptoms (Mandal and Mukherji 2000; Joshi and Swami, 2007; Tripathi *et al*., 2009). Categorization of plants as sensitive or tolerant was determined by the level of these parameters in plants and thus plants show different susceptibility to different pollutants. Sensitive species are an early indicator of pollution and the tolerant species help in reducing the overall pollution load (Singh and Rao, 1983; Subrahmanyam *et al*., 1985; Nrusimha *et al*., 2005). Sensitivity and response of plants to air pollutants varied with the plant species, could be assessed by air pollution tolerance index (APTI). APTI is an unique index, incorporating four different biochemical parameters i.e. total chlorophyll, pH of leaf extract, ascorbic acid and relative water content (RWC) (Shannigrahi *et al*., 2003). These studies provide an impetus in assessing the sensitivity and tolerance of several plant species. Further, these studies indicated the suitability of plant species in remediation of air pollution in and around urban /industrial area. Sensitive plant species were suggested as bio indicator (Raina and Sharma, 2006; Tripathi *et al*., 2009). Bio indicators are useful due to their high sensitivity towards the broad range of air pollutants (De. Temmerman *et al*., 2004; Tripathi *et al*., 2009). Tolerant species help in reducing the overall pollution load of atmosphere. Mizoram Pollution Control Board and one preliminary study in Aizawl (Lalrinpuii and Lalramnghinglova, 2008) recorded the level of suspended particulate matter (SPM) and respirable particulate matter (RPM) above permissible limit of National Ambient Air Quality Standards (NAAQS). Further, particulate matter below the size of 10 microns (PM_{10}), are specifically hazardous to human health (Pandey *et al*., 2005; Rai, 2011a; Rai, 2011b; Rai, 2013). In the light of these facts, it is pertinent to characterize the air quality of ecologically sensitive regions like Aizawl, Mizoram and concomitantly suggest some remedial measures. Present study, intended to assess the suitability, selectivity and tolerance limit in terms of APTI values of five selected plant species grown along the road side of Aizawl, Mizoram adjacent to the national highway. Further, anticipated performance index (API), which included APTI, physiognomy or biological characters and certain socio-economic parameters were also studied in order to evaluate the feasibility of these plants for green belt development.

MATERIALS AND METHODS

Study area

Present work was performed in Aizawl, Mizoram, North East India (21°58′- 21°85′ N and 90°30′- 90°60′E), the capital city of the state located 1132 meter above sea level (ASL). The study area comes under Indo Burma hotspot region. The altitude in Aizawl district varies from 800 to 1200 meter ASL. The climate

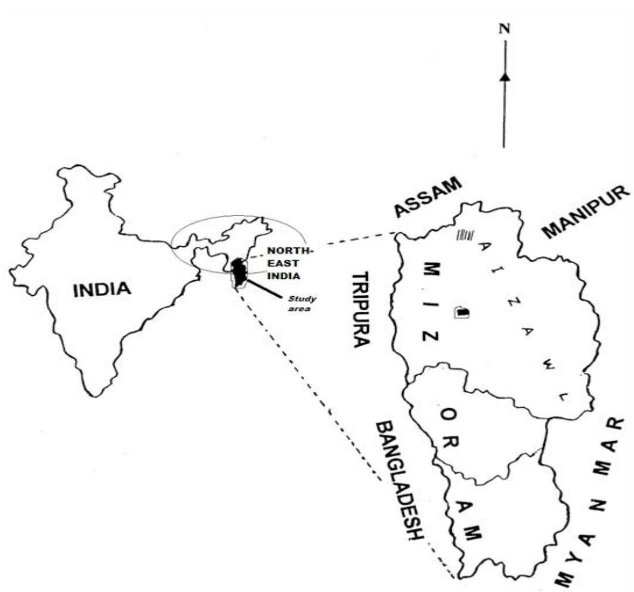

Figure 1: Location of study area: Aizawl (Mizoram), North East India

of the area is typically monsoonal. The annual average rainfall is amounting to ca 2350 mm. This area experienced with distinct seasons. The ambient air temperature normally ranged from 20 to 30°C in summer and 11°C to 21°C in winter (Laltlanchhuanga, 2006).

Ambient air quality monitoring

The air quality in Aizawl is primarily affected by the vehicular exhausts and biomass burning. The vehicular exhausts contribute a significant amount to the air pollution in the city. The pollutants include Suspended particulate matter (SPM), Respirable suspended particulate matter (RSPM), Sulphur dioxide (SO_2) and nitrogen dioxide (NO_2). Ambient air quality for SPM, RSPM, SO_2 and NO_2 were done twice in a month for the winter season, 2011 and 2012. The representative months considered were December, January and February. High Volume Air Sampler (Envirotech model, APM-460NL) with gaseous attachment (Envirotech model, APM-411TE) was used to monitor the air quality. RSPM were trapped by glass fibre filter papers and SPM were collected in the separate containers at average air flow rate of 1.5 m^3/min. The sampler was run for 24 hour on eight hourly basis and triplicate samples were collected at each time. West and Gaeke method (1956) and Sodium Arsenite method (Margeson, 1977) were used for the analysis of SO_2 and NO_x respectively.

Selection of sampling site and sampling details

The research work was mainly confined near roadside. Three sampling points were selected for air quality monitoring between the distance (3.53 to 5.77 km) estimated for the maximum amount of air pollutant accumulation and five common roadside plant species having same age were collected from these sites of Aizawl city for the study. On each plant three branches directly facing the roadside were tagged and mature leaf samples from the lower branches at a height of 2-4m from the ground level were collected at 10 day interval in the month of December, January and February in 2011 and 2012. The collected leaves were placed in the marked polythene bags and brought to the laboratory where it was stored at -20°C for further analysis.

Biochemical estimation

Various biochemical parameters such leaf extracts pH (Singh and Rao, 1983), relative water content (Sen and Bhandari, 1978), total chlorophyll (Arnon, 1949), ascorbic acid (Keller and Schwager, 1977) were done for the collected leaf samples.

APTI and API calculation

APTI of each species was calculated by incorporating leaf extract pH, total chlorophyll, ascorbic acid content and relative water content into the following mathematical expression given by Singh and Rao (1983).

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

Where,

A = Ascorbic acid (mg/g)

T = Total chlorophyll (mg/g – f .w)

P = pH of the leaf extract.

R = Relative water content of leaf (%).

It was necessary to investigate the potential or suitability of different plants for Green Belt development. Therefore, on the basis of the resultant APTI value and some relevant biological and socioeconomic characters, the API was determined for each plant species as shown in Table 2 (Shannigrahi *et al.*, 2003; Mondal *et al.*, 2011). Plants were further graded into different performance categories as per the API value. Based on the current grading system, a tree can secure a maximum of 16 positive points. These points were scaled to a percentage system and based on the score obtained, the category has been assessed.. SPSS ver. 10 was used for statistical analysis

RESULTS AND DISCUSSION

Air pollutants

The concentration of air pollutants recorded during December 2011 to February 2012 has been presented in Table 1. The average value for SPM varies from 210 ± 42.06 to 260 ± 43.61 μg m^{-3}and the highest concentration (260 ± 43.61 μg m^{-3}) was observed in the month of December. The average value for RSPM varies from 110 ± 33.42 to 127 ± 43.61 μg m^{-3} and the highest concentration was observed in the month of December. The average value for SO_2 varies from 1.03 ± 0.03 to 4.13 ± 0.06 μg m^{-3}and the highest concentration (4.13 ± 0.06 μg m^{-3}) was observed in the month of December. The average value for NO_2 varies from 14 ± 2.76 to 18 ± 2.90 μg m^{-3} and the highest concentration (18 ± 2.90 μg m^{-3}) was observed in the month of January. The sampling sites for the air quality monitoring were residential area. The standard limit prescribed by Central Pollution Control Board (CPCB) for pollutant concentration like SPM, RSPM, SO_2 and NO_2 for residential site are 200,100,80 and 80 μg m^{-3}respectively but the present concentration of RSPM and SPM are much higher than the prescribed limits of CPCB while the concentration of NO_2 and SO_2 was still under the prescribed limit. The present concentrations are well enough to affect the human health and can cause biochemical alteration in the growing plants.

Table 1: Ambient air quality of the study area 2011 and 2012

Month	SPM (μg m^{-3})	RSPM (μg m^{-3})	SO_2 (μg m^{-3})	NO_2 (μg m^{-3})
Dec	260±43.61	127±28.06	4.13±0.06	16±2.23
Jan	250±40.01	117±30.08	3.04±0.02	18±2.90
Feb	210±42.06	110±33.42	1.03±0.03	14±2.76
CPCB standard	200.00 μgm^{-3}	100.00 μgm^{-3}	80.00 μgm^{-3}	80.00 μgm^{-3}

Biochemical characteristics

The biochemical characteristics of selected plants and their APTI values for the month of December, January and February are shown in the Tables 2, 3 and 4 respectively. The highest value for leaf extract pH was observed in *Artocarpus heterophyllus* (6.31 ± 0.17) and lowest in *Bougainvillea spectabilis* (4.75 ± 0.36) in the month of December and January respectively. pH is a biochemical parameter that act as an indicator for sensitivity to air pollution (Joshi and Bora, 2011; Scholz and Rick ,1997). It has been reported that in the presence of an acidic pollutant which may be due to the presence of SO_2 and NO_X in the ambient air, the leaf pH is lowered and the decline is greater in sensitive than that in tolerant plants (Singh and Verma, 2007; Rai and panda, 2013). A pH on higher side improves tolerance against air pollution (Agarwal, 1986; Shannigrahi *et al.*, 2004).

The highest relative water content was observed in *Artocarpus heterophyllus* (89.04 ± 1.34) and found lowest in *Lagerstroemia speciosa* (65.06 ± 2.08) in the month of January. In the month of December and February it ranged from 75.60 ± 2.56 to

Table 2: Assessment of Air Pollution Tolerance Index of tree species for the month of December 2011

Plant species	pH	Relative water content (%)	Ascorbic acid (mg/g)	Total chlorophyll (mg/g)	APTI
Bougainvillea spectabilis	5.95±0.15	75.60±2.56	0.50±0.14	0.75±0.18	7.8
Psidium guajava	5.56±0.20	84.95±2.96	0.57±0.07	1.23±0.11	8.8
Lagerstroemia speciosa	5.22±0.18	68.88±2.02	0.22±0.14	0.21±0.16	7.0
Artocarpus heterophyllus	6.31±0.17	88.41±1.6	0.64±0.11	1.95±0.15	9.3
Hibiscus rosasinensis	5.21±0.23	86.44±1.34	0.52±0.10	1.07±0.22	8.9

Table 3: Assessment of Air Pollution Tolerance Index of tree species for the month of January 2012

Plant species	pH	Relative water content (%)	Ascorbic acid (mg/g)	Total chlorophyll (mg/g)	APTI
Bougainvillea spectabilis	4.75±0.36	77.08±2.12	0.47±0.10	1.04±0.17	7.9
Psidium guajava	6.01±0.31	85.31±1.16	0.51±0.02	1.39±0.11	8.9
Lagerstroemia speciosa	5.42±0.34	65.06±2.08	0.18±0.01	0.40±0.10	6.6
Artocarpus heterophyllus	6.05±0.10	89.04±1.34	0.53±0.09	1.95±0.15	9.3
Hibiscus rosasinensis	5.39±0.25	82.09±2.37	0.44±0.16	1.12±0.23	8.4

Table 4: Assessment of Air Pollution Tolerance Index of tree species for the month of February 2012

Plant species	pH	Relative water content (%)	Ascorbic acid (mg/g)	Total chlorophyll (mg/g)	APTI
Bougainvillea spectabilis	5.07±0.19	76.24±1.47	0.42±0.11	0.98±0.19	7.8
Psidium guajava	5.36±0.18	84.06±2.61	0.45±0.12	1.42±0.12	8.7
Lagerstroemia speciosa	5.40±0.26	70.03±1.56	0.17±0.10	0.74±0.18	7.1
Artocarpus heterophyllus	5.82±0.22	84.28±1.14	0.56±0.13	2.48±0.11	8.9
Hibiscus rosa sinensis	4.95±0.31	85.11±1.70	0.47±0.06	1.26±0.21	8.8

Table 5: Gradation of plant species on the basis of air pollution tolerance index (APTI) and other biological and socio-economic characters (After Tiwari *et al.*, 1993; Shannigrahi *et al.*, 2003)

Attributes			
(a) Tolerance		7.0-8.0	+
Air pollution tolerance index (APTI)	8.1-10.0	+ +	
		10.1-11.0	+ + +
		11.1-12.0	+ + + +
		12.1-13.0	+ + + + +
(b) Biological and socio-economic	(i) Plant habit	Small	-
		Medium	+
		Large	+ + +
	(ii) Canopy structure	Sparse/irregular/globular	-
		Spreading crown/open/semidence	+
		Spreading dense	+ +
	(iii) Type of plant	Deciduous	-
		Evergreen	+
	(iv) Laminar structure	Small	-
		Medium	+
		Large	+ +
		Smooth	-
		Coriaceous	+
		Delineate	-
		Hardy	+
	(v)Economic value	Less than three uses	-
		Three or four uses	+
		Five or more uses	+ +

*Maximum score that can be attained: 16

Table 6: Anticipated performance index (API) of plant species

Grade	Score (%)	Assessment of plant species
0	Up to 30	Not recommended for plantation
1	31-40	Very poor
2	41-50	Poor
3	51-60	Moderate
4	61-70	Good
5	71-80	Very good
6	81-90	Excellent
7	91-100	Best

88.41 $\pm$ 1.6 and 70.03 $\pm$ 1.56 to 85.11 $\pm$ 1.70 respectively. High water content within plant body helps to maintain its physiological balance under stress condition. It also serves as an indicator of drought resistance in plants (Dedio, 1975; Seyyednjad *et al.*, 2011).Reduction in RWC of plant species is due to impact of pollutant on transpiration rate in leaves(Swami et al,2004). If leaf transpiration rate is reduced due to air pollution, plants lose ability to pull water and minerals from roots for biosynthesis. Therefore, maintenance of RWC by the

Table 7: Evaluation of plant species, to be considered for Green Belt development, on the basis of APTI value, biological characters/physiognomy and socio-economic characters

Plant	APTI	Tree habit	Canopy structure	Type of tree	Laminar structure size	texture	Economic importance	Hardi-ness	Grade allotted	% scoring	API grade
Bougainvillea spectabilis	+	+	+	+	+	“	+	-	6	37.50	1:Very poor
Psidium guajava	+ +	+	_	_	+	+	+ + +	+	9	56.25	3: Mode-rate
Lagerstroemia speciosa	_	+	+	+	+ +	“	+	+	7	43.75	2:Poor
Artocarpus heterophylla	+ +	+ +	+ +	+	+ +	+	+	+	12	75.00	5: Very good
Hibiscus rosa sinensis	+ +	+	+	+	+	+	+	+	9	56.25	3: Mode-rate

Table 8: Anticipated performance of different plant species

Plant species	Grade allotted Total plus	% Score	API gradation	Assessment
Bougainvillea spectabilis	6	37.50	1	Very poor
Psidium guajava	9	56.25	3	Moderate
Lagerstroemia speciosa	7	43.75	2	Poor
Artocarpus heterophyllus	12	75.00	5	Very good
Hibiscus rosa sinensis	9	56.25	3	Moderate

Table 9: Correlation between air pollutants and biochemical parameters (Govindaraju *et al.*, 2011)

	Relative water content	pH	Total chlorophyll	Ascorbic acid
SPM	Negative	Positive	Negative	Positive
RSPM	Negative	Positive	Negative	Positive
SO2	Negative	Positive	Negative	Positive
NO2	Negative	Negative	Negative	Positive

plant may decide the relative tolerance of plants towards air pollution (Verma, 2003; Rai *et al*., 2013).

The highest total chlorophyll content (in mg/g fresh wt.) was recorded in *Artocarpus heterophyllus* (2.48 ± 0.11) in the month of February and lowest in *Lagerstroemia speciosus* (0.21 ± 0.16) in the month of December. In January it varied from 0.40 ± 0.10 to 2.36 ± 0.11. The chlorophyll content of plant varies from species to species and also with the pollution level. Higher pollution load tends to decrease the total chlorophyll content (Rai and Panda, 2013). Rao and Leblanc (1966) have also reported reduction in chlorophyll content brought by acidic pollutants like SO_2 which causes phaeophytin formation by acidification of chlorophyll. Reduction in chlorophyll content in variety of crop plant due to NO_2, SO_2 and O_3 exposure have also been reported by Agrawal *et al*. (2003). Higher chlorophyll content in plant might favor tolerance to pollutants where as a considerable loss in total chlorophyll support the sensitivity nature of plant species. Several studies (Tripathi and Gautam, 2007; Mir *et al*., 2008; Jyothi and Jaya, 2010) also suggested that high level of automobile pollution decreased the chlorophyll content in higher plants near road side. Chlorophyll content of plant signifies its photosynthetic activity. Degradation of photosynthetic pigment has been widely used as an indication of air pollution (Ninave *et al*., 2001).

The highest content of ascorbic acid was found in *Artocarpus heterophyllus* (0.64 ± 0.11 mg/g fresh weight) in the month of December and the lowest value was recorded (0.17 ± 0.10 mg/g fresh weight) for *Lagerstroemia speciosa* in the month of February. It ranged between 0.18 ± 0.01 and 0.53 ± 0.09mg/g) at January month. The increased level of ascorbic acid was reported to attribute in the defense mechanism of the respective plant (Tripathi and Gautam, 2007; Cheng *et al*., 2007). Increased level of ascorbic acid in leaves will increase air pollution tolerance in these plant (Chaudhury and Rao, 1977) whereas lower ascorbic acid content in the leaves of other plant species studied, which supported the sensitive nature of these plants towards pollutants particularly automobile exhaust. Ascorbic acid was regarded as an antioxidant, found in large amount in all growing plants and influenced greatly to adverse environmental condition including air pollution (Keller and Schwager, 1977; Lima *et al*., 2000; Arora *et al*., 2002).Some investigators have established direct relationship between endogenous level of ascorbic acid and plant susceptibility to pollutants (Lee *et al*., 1984; Chen, Lucas and Wellburn., 1990). Tripathi and Gautam (2007) reported pollution load dependent increase in ascorbic acid content of all the plant species may be due to the increased rate of production of ROS during photo-oxidation process Therefore all these biochemical parameters constitute APTI in totality.

The highest APTI value was scored by *Artocarpus heterophyllus* (9.3) in December and January. The lowest value was observed in *Lagerstroemia speciosa* (6.6) in January and in the month of February it varied from 7.1 to 8.9. The significance of APTI in determining the tolerance along with the sensitivity of plant species were investigated by several authors (Agarwal and Tiwari, 1997; Dwivedi and Tripathi, 2007; Prajapati and Tripathi, 2008; Liu and Din, 2008; Dwivedi *et al*., 2008; Lakshmi *et al*., 2009; Jyothi and Jaya, 2010; Pathak *et al*., 2011). APTI determination for plants is an important parameter for future plantation, since plants have the ability to serve as quantitative and qualitative indices of pollution control (Jyothi and Jaya, 2010). It could be suggested from low APTI values exhibited by some plant species that they were sensitive to pollutants, which was also evident from the variations in the biochemical parameters analyzed in this study.

Evaluation of API and assessment of different plants based on their API values (Tables 5, 6, 7 and 8) reveals that *Artocarpus heterophyllus* is most tolerant and can be expected to perform well as it falls under the category of very good performer and its plantation in main Aizawl city as well as peri-urban area of Aizawl is recommended. *Psidium guajava* and *Hibiscus rosa sinensis* were moderately suitable for plantation in Green Belt and their plantation in town squares and on the outskirts of villages and towns may considerably reduce air pollution. In the remaining plant species, one is identified as poor performer and one is coming under very poor category. The performance of different plants may vary in urban (densely populated) and hilly areas (sparsely populated). Similar findings were reported elsewhere for the systematic and effective development of green belts (Prajapati and Tripathi, 2008). Study on air pollution Biomonitoring in an urban area of Varanasi by Pathak *et al*. (2011) recommended *Ficus infectoria* as the best performer while *Mangifera indica* and *Ficus religiosa* were classified into the excellent performer category. Study by Pathak *et al*. (2011), further recommended the green belts as an effective tools for mitigation of traffic generated noise. Further, the parameters of the APTI have been correlated with the pollutant concentration. It has been found that the relative water content, total chlorophyll are negatively correlated and ascorbic acid is positively correlated with all the pollutants. The pH values are negatively correlated in the case of NO_2 (Table 9).

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