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Air pollution tolerance index and anticipated performance index of 15 species considered for green belt development in Virudhunagar

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Abstract
In this research work, the Air pollution Tolerance Index of fifteen species collected from three different locations like Residential area, Industrial area and Heavy traffic area in Virudhunagar has been evaluated by analyzing biochemical parameters like Ascorbic acid, Chlorophyll, pH and Relative water content. The high values of Air pollution Tolerance Index were recorded in Moringa olifera, Azardiracta indica, Delonix regia, Mangifera indica, Eugenia jambolana and Fiscus religiosa for winter and summer season. The Air pollution Tolerance Index of plant species was also calculated by their Anticipated Performance Index together with other socio-economic and biochemical parameters. According to Anticipated performance index of most tolerant plant species for green belt development were Mangifera indica & Fiscus religiosa for road side and Azardiracta indica & Eugenia jambolona for industrial area.

Keywords: air pollution tolerance index, chlorophyll, PH, relative water content and anticipated performance index

1. Introduction

According to a study by Dwivedi and Tripathi (2007) [2], the distribution of plant diversity highly depends on the presence of air pollution in the ambient air and sensitivity of plants. Studies has also shown the impacts of air pollution on Ascorbic acid content [3], Chlorophyll content [4], leaf extract pH [5] and relative water content [6]. These separate parameters give conflicting results for same species [7]. The human activities include physical disturbance that can cause reversible and irreversible effects on plants. Plants can be used as both passive biomonitors and biomitigators to indicate the environmental air quality and reduce the pollution level in a locality [8]. Sensitivity and response of plants to air pollutants is variable as it depends upon the nature of pollutants [9].

Trees also remove pollution by intercepting airborne particles. The intercepted particle often is resuspended to the atmosphere, washed off by rain or dropped to the ground with leaf and twig fall. For this purpose, evaluation of plants with respect to their tolerance level to air pollution may be essential. To evaluate the tolerance level of plant species to air pollution, Singh and Rao, (1983) [10] used leaf's biochemical parameters to drive an empirical number indicating the Air Pollution Tolerance Index (APTI). Air pollution tolerant index is an index that denotes capability of a plant to combat against air pollution. Plants which have higher index value that are tolerant to air pollution can be a sink to mitigate pollution while plants with low index value show less tolerance and can be used to indicate levels of air pollution. There were evident, that the plants showed varied degree of tolerance index to air pollution. Based on the APTI values the plants are conveniently grouped as tolerant, intermediate and sensitive [11].

In the present study, in order to find the determination of tolerance or sensitivity of selected tree species the APTI have been identified, using biochemical parameters. The biochemical parameters analyzed and APTI were computed in both polluted

And control region for each type of tree. Air pollution is the harmful introduction into the atmosphere, such as chemicals,

Particulate matter or biological materials that cause harm and discomfort to humans or other living organisms also damage the environment [12]. Various efforts have been done for environmental restoration in India but still it seems to be a formidable task. Plants the main Green Belt (GB) component act as a sink and as living filters to minimize air pollution by absorption, adsorption, accumulation and metabolization without sustaining serious foliar damage or decline in growth thus improving air quality by providing oxygen to the atmosphere [13, 14]. Air pollution can directly affect plants via leaves or indirectly via soil acidification [15]. The high sensitivity of plants towards some pollutants means that a great variety of plants can be used as bio indicators of air pollution [16]. The main focus of this work is to provide an assessment of the use of biochemical parameters of plants for GB. Green belt may be defined as a strip of trees that significantly attenuate the air pollution by intercepting and assimilating the pollutants in a sustainable manner.

The term green belt meant generally any swath of trees in open space separating or interrupting urban development. So, these biochemical indicators can be used for assigning APTI for plants in selected areas. Plants sensitivity and tolerance to air pollutants varies with these parameter [17]. The Air Pollution Tolerance Index (APTI) of many plant species has been evaluated by analyzing important biochemical parameters. The Anticipated Performance Index (API) of these plant species was also calculated by considering their APTI values together with other socio-economic and biological parameters. Based on these two indices, the most suitable plant species for green belt development in urban areas were identified and recommended for long-term air pollution management (Prajapati *et al*., 2008) [18, 19].

2. Materials and methods

2.1 Selection of Sample Area of study

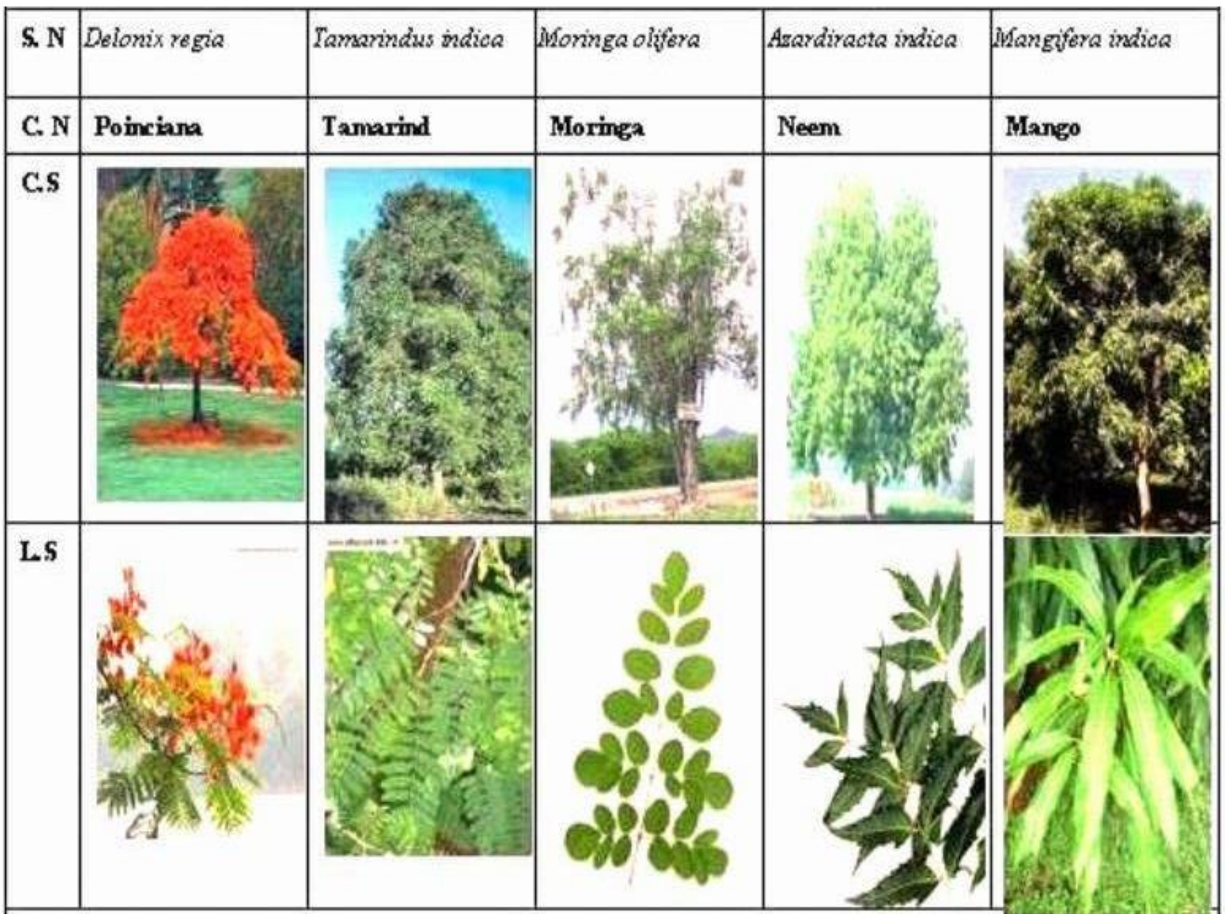
The present research work was mainly confined in Virudhunagar which is located in southern part of Tamil Nadu, India. It is a Municipality, spread over an area of 6.39 sq.km holding a population of 72,081 as on 2001(adopting population projection, it was interpolated that the population of this town was predicted as 77,449 in 2009). It is located at 9º35’ North latitude, 77º57’ East longitude and at 101.3 m above mean sea level. The climate of this town is hot and dry throughout the year and April to June being the hottest months. The maximum temperature is rarely above 38.5ºC and the minimum temperature is 34.2ºC. The town receives rainfall mostly during Northeast monsoon, and the average rainfall is 780 mm per annum.

2.2 Selection of Plant species.

There were fifteen tree species such as Delonix regia, Tarmarindus indica, Moringa olifera, Azardiracta indica, Mangifera indica, Millingtonia hortensis, Pongamia glabra, Polyalthia longifolia, Eugenia jambolana, Pithecellobium dulce, Ficus religiosa, Ficus benghalensis, Tectona grandis, Eucalyptus globules and Ficus benjamina which are commonly seen in this area were selected for this study is shown in Fig 1(a), 1 (b) and 1 (c).

2.3 Sample collection

Plants were randomly selected from the immediate vicinity of the station. This is designated as experimental site. Three replicates of fully matured leaves were collected and immediately taken to the laboratory for analysis. A composite sample of each plant species was obtained before analysis. Leaf samples were preserved in refrigerator for further analysis. A site nearby with similar ecological conditions was selected as the control site (S1). Utmost care was taken for sample collection from each sampling location Site 1 (S1) (Control area), Site 2 (S2) (Heavy traffic area) and Site3 (S3) (Industrial area).



S.N: Scientific name, C.N: Common name, C.S: Canopy Structute, L.S: laminar Structure

Fig 1(a): Selected plants with their common and scientific name showing canopy, laminar stuctures

S. N	*Millingtonia hortensis*	*Pongamia glabra*	*Polyalthia longifolia*	*Eugenia jambolana*	*Pithecellobium dulce*
C. N	**Tree jasmine**	**Pongam**	**Buddha tree**	**Jamun**	**Madras thorn**
C.S					
L.S					

S.N: Scientific name. C.N: Common name, C.S: Canopy structute, L.S: Laminar structure.

Fig 1(b): Selected plants with their common and scientific name showing canopy, laminar structures

S. N	*Ficus religiosa*	*Ficus benghalensis*	*Tectona grandis*	*Eucalyptus globulus*	*Ficus benjamina*
C. N	**Peepal**	**Banyan**	**Teak**	**Blue gum**	**Weeping fig**
C.S					
L.S					
S.N: Scientific name, C.N: Common name, C.S: Canopy structute, L.S: Laminar structure.					

S.N: Scientific name, C.N: Common name, C.S: Canopy Structute, L.S: laminar structure

Fig 1(c): Selected plants with their common and scientific name showing canopy, laminar structures

2.4. Analysis of biochemical parameters

The collected leaf samples were analyzed for different biochemical parameters like ascorbic acid, total chlorophyll, leaf extracts pH and relative water content using the standard procedures. Estimation of total chlorophyll content (TC) was done according to the method described by Arnon (1949) [20]. Ascorbic acid was estimated using the method developed by Agarwal (1985) [21].

Relative Water Content (RWC) was determined by using the method described by Barrs and Weatherly (1962) [22]. For the measurement of leaf extract pH, 2g of the sample was homogenized with 20ml of deionized water and the pH of the suspension was measured with a digital pH meter with a glass combined electrode [24].

2.5. Computation of APTI

Air pollution Tolerance Index (APTI) determination was done by the method given by Singh and Rao (1983) [10] using the formula

$APTI = [A (T+P) + R]/10$

Where: A = Ascorbic acid content (mg/g), T = Total chlorophyll (mg/g), P = pH of leaf extract, R = relative water content of leaf (%).

2.6. Calculation of Anticipated Performance Index (API)

The results of APTI value combined with some related biological and socio-economic characters such as plant habit, canopy structure, type of plant and economic value. Depending upon these characters different grades (+ or -) given to the selected plants and the plants scored according to their grades [30, 31]. The criteria given for calculating the API of different plants are given in Table 1 and Table 2.

Table 1: Anticipated Performance Index (API) of plant species

	% Score	Assessment category
0	Up to 30	Not recommended
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

Table 2: Gradation of plant species on the basis of APTI and other socio-economic and biochemical characters

Grading characters			Assessment Pattern	Allotted grade
1. Tolerance	Air Pollution Tolerance Index (APTI)		12.0-16.0	+
			16.1-20.0	++
			20.1-24.0	+++
			24.1-28.0	++++
			28.1-32.0	+++++
			32.1-36.0	++++++
2.biochemical and socio-economic character	i. Plant habit		small	-
			medium	+
			large	++
	ii. Canopy structure		Sparse/ irregular/ globular	-
			Spreading crown/ open/ semi	+
			Spreading dense	++
	iii. Type of Plant		Deciduous	-
			Ever green	+
	iv. Laminar structure	size	small	-
			medium	+
			large	++
		texture	smooth	-
			coriaceous	+
		hardiness	delineate	-
			hardy	+
	v. Economic value		Less than three uses	-
			Three or four uses	+
			Five of more uses	++

2.7. Statistical treatment

This study was carried out for the period of one year (May 2010 to May 2011). Statistical treatment of the data was carried out by using SPSS version.17. Statistical difference of the means was checked out using Analysis of Variance (ANOVA) to isolate which group(s) differ from the others with respect to the seasons, plants and study stations. Linear correlation and regression analysis were performed between independent variables such as ascorbic acid, total chlorophyll, leaf extract pH, RWC and dependent variable of this work APTI.

3. Results and Discussion

3.1 Monthly variation of APTI

All biochemical parameters that are analyzed for APTI plays significant role to determine resistivity and susceptibility of plant species [32]. In the month of December 2010 (Fig 2) APTI value ranges from 2.97 to 12.09. At site1 the lowest value is observed in F. bengamina (2.97) and the highest value is recorded in A. indica (9.96). Almost all the species showed variation in their tolerance towards air pollution between control and polluted sites. Exceptionally M. hortensis showed no significant variation

(4.94 at S_1, 4.83 at S_2 and 4.75 at S_3). Species like T. indica (4.82to 7.24), P. longifolia (6.89 to 8.43), F. religiosa (5.98 to 7.46), F. benghalensis (6.35 to 9.49), T. grandis (5.52 to 7.50) and F. bengamina (2.97 to 8.69) showed tolerance at polluted sites. F. bengamina exhibited maximum variation. Plants such as M. indica (12.09) and E. jambolana (9.73) showed higher tolerance at S_2 and S_3 respectively.

During the month of January 2011, the calculated APTI values ranged between 2.40 to 10.97. Plant species like P. longifolia, E. jambolana, F. benghalensis, E. globulus exhibited steady increase of APTI value from site1 to site 3. The values found to be decreased from control to polluted sites in trees like M. olifera (9.14 to 7.19) and P. dulce (9.82 to 6.04). Decrease may be due to reduction in the tolerance for pollutants during that cold month [33]. Notable increase was observed in tree species like F. benghalensis (4.25 to 9.86), T. grandis (5.13 to 7.51), E. globulus (5.12 to 8.27) and F. bengamina (3.84 to 9.01) at site 3 and these trees showed higher tolerance for industrial pollution. M. indica (9.96) exhibited higher tolerance for automobile pollution.

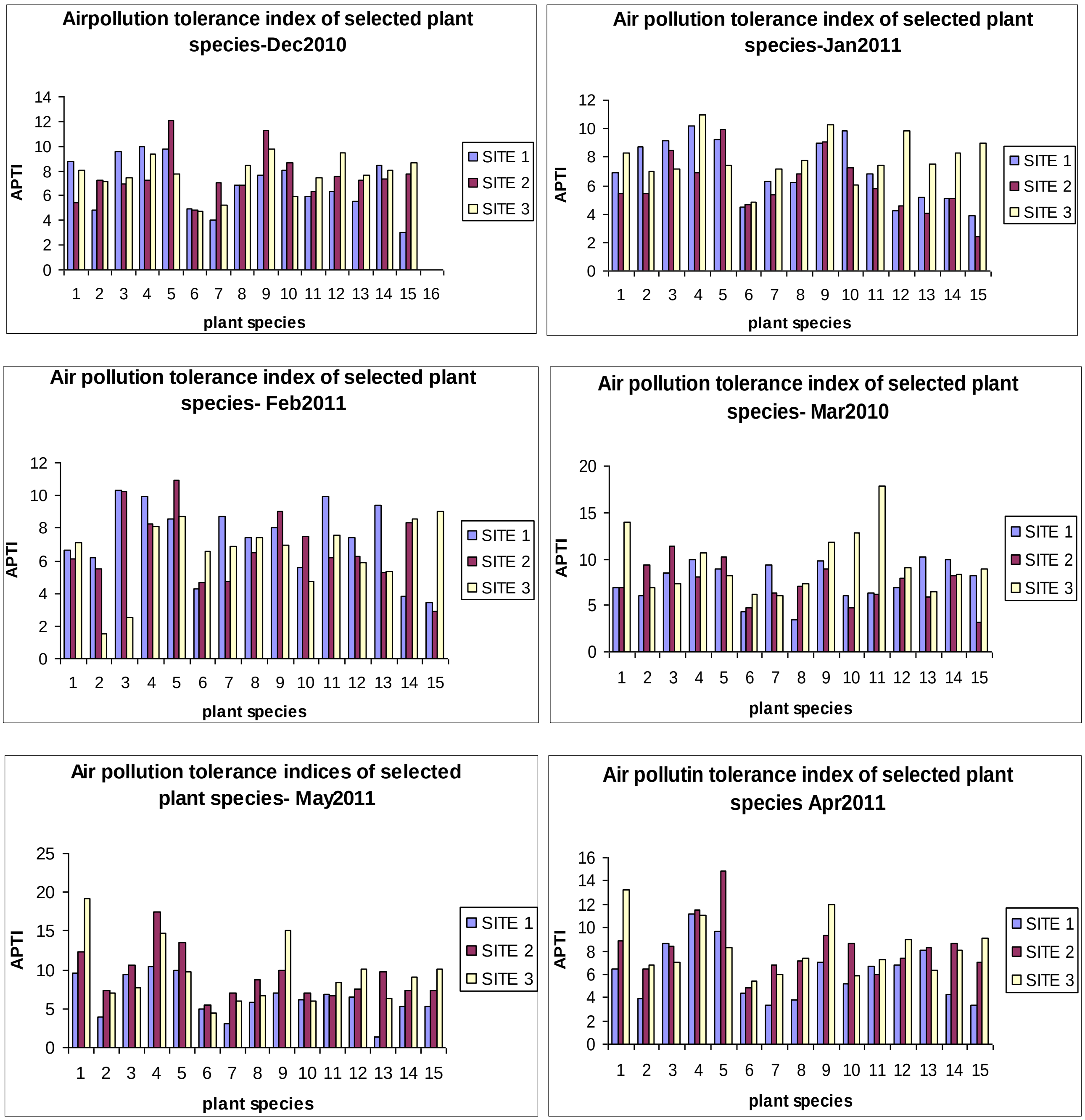


Fig 2: Variation of Air pollution tolerance index of plant species in selected sites at Virudhunagar for the month of –December 2010 to May 2011

It was observed in the month of February 2011(Fig 2) that almost all the species observed with higher tolerance than the values observed for the month January 2011. In contrary species like T. indica (6.22 to 1.49), M. olifera (10.32 to 2.51), A. indica (9.95 to 8.07) and F. benghalensis (7.42 to 5.91) became sensitive. The maximum and minimum values observed were 10.91 and 2.89

respectively. It was observed that M.indica exhibited higher tolerance for automobile exhausts (at S_2) (10.91) and A.indica showed higher tolerance for industrial air pollution (8.07).

It was found out evidently in the month of March 2011(Fig 2) the highest tolerance observed in F.religiosa (17.83) at S_3. The analyzed values ranged between 3.16 to 17.83. Species like T. indica (6.01 to 9.31), M.hotensis (4.25 to 6.25), P.longifolia (3.38 to 7.38) and F.benghalensis (6.95 to 9.12) showed increased tolerance to air pollution at site 2 than the control site (S_1). Trees such as D.regia (13.89), E.jambolana (11.82), and P.dulce (12.82) showed significant increase in their tolerance towards industrial air pollutants.

Analyzing the data obtained for the month of April 2011(Fig 2) most of the selected species showed increased APTI at all the study sites but it varied with the pollution load [34]. The calculated values ranged from 3.36 to 14.86. The tree species M.indica was relatively tolerant among the selected tree species for automobile exhausts (Site2). F. benjamina showed relatively low value at S_1. Tree species M. olifera (8.60 to 6.98) exhibited decrease in tolerance towards traffic and industrial pollutants. Plants such as D. regia (13.25), E.jambolana (11.96), F. benghalensis (8.96) and F. benjamina (9.03) were observed with significant higher tolerance at S_3.

On the basis of APTI data for the month of May 2011(Fig 2) the value ranged between 1.45 and 19.12. The highest tolerance was shown by D.regia at industrial site. The least value exhibited by T.grandis at residential area. Plants such as A. indica (17.49), M.indica (13.55), P.longifolia (8.80) and T.grandis (9.73) exhibited higher value at S_2 than other selected sites. D.regia (19.12), E.jambolana (15.14), F.benghalensis (10.06) and F.bengamina (10.12) exhibited significant tolerance at S_3 than the control area (S_1).

3.2 Seasonal variation of biochemical parameter value of plants

3.2.1. Variation of chlorophyll content during winter season

Out of 15 species analyzed, species like D.regia, M.hortensis, F.religiosa and F.benhalensis exhibhited lower value of chlorophyll content at the area polluted by automobile exhausts (S_2) and higher value of chlorophyll content at industrial site (S_3). At the same time species like E.jambolana, P.dulce and F.benjamina showed significant decrease of chlorophyll content at site 3 compared to the value recorded at site 1 (control). Trees such as M.olifera and E.globulus showed increasing trend of recorded value from S_1 to S_3. It also varied with the tolerance as well as sensitivity of the plant species that is higher the sensitive nature of the plant species lowers the chlorophyll content. Irrespective of study stations, higher levels of total chlorophyll was observed in M.indica (11.69 mg g^{-1},11.85 mg g^{-1},12.32 mg g^{-1}at site 1, site 2 and site 3 respectively) and this higher levels of total chlorophyll observed may be due to its tolerance nature.

3.2.2 Changes in Ascorbic acid content during winter

At control site the highest and the lowest values of ascorbic acid content was observed in A.indica (2.46 mg g^{-1}) and in F.benjamina (0.13 mg g^{-1}) at control site (S_1). It was also observed that the highest value was shown by M.indica (2.42 mg g^{-1}) and lowest value was observed in F.benjamina (0.13 mg g^{-1}) respectively. It was observed that the highest value in the plant E.jambolana (2.60 mg g^{-1}) and lowest value in M.olifera (0.23 mg g^{-1}) were exhibited at the area polluted by industrial emissions (S_3). Present study showed elevation in the concentration of ascorbic acid with respect to the control site in E.jambolana, F.religiosa, F.benghalensis, E.globulus and F.benjamina. Pollution load increases the ascorbic acid content of all the plant species which may be due to the increased rate of production of reactive oxygen species (ROS) during photo-oxidation of SO2 to SO3 and where sulfites are generated from SO2 absorbed by plants.

3.2.3 Changes in leaf extract pH during winter

F.benhalensis showed higher value of leaf extract pH and T. indica observed with lower pH at all the selected sites. Plant species such as M.hortensis, T.grandis and E.globulus showed increasing trend of pH. Plants like P.glbra, P.longifolia, E.jambolana exhibiting decreasing trend or it gets acidic. Tree species such as D.regia and M.indica showed increase in the value of pH at S_3 but there was no significant variation was observed at site 2. Tree species such as M.indica, M.olifera and F.religiosa were observed with low pH due to air pollutants at site 2 and higher pH at site 3 than the control area (S_1).

3.2.4 Changes in relative water content during winter

Relative Water Content (RWC) of a leaf is the water present in it relative to its full turgidity. The high relative water content was recorded in the species M.olifera (90.24 %), E.jambolana (75.07 %), P.logifolia (72.12 %) at site 1, site 2 and site 3 respectively. Similarly the lowest value of RWC was recorded in F.benjamina (32.08 %) at site1, M.hortensis (35.90 %) at site 2 and P.dulce (45.17 %) at site 3. Present study showed higher relative water content with respect to the control site in M.indica, P.longifolia, E.jambolana and E.globulus at site 2 which was polluted by automobile emissions and road dusts. Plant species like D.regia, A.indica, M.hortensis, F.benhalensis, T.grandis, E.globulus and F.benjamina showed higher RWC at site 3 compared to control area. It was also observed that decreasing trend of RWC towards polluted sites exhibited by plant species T.indica, M.olifera, P.dulce and F.religiosa.

Table 3: Biochemical parameters of selected plant species at different sites (WS)*

Species	R (%)			pH			T(mg/g)			A(mg/g)		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
D. regia	65.97	41.25	72.00	6.06	6.06	6.03	2.32	2.26	11.58	0.99	1.88	0.68
T. indica	55.57	45.97	47.12	4.38	3.53	3.56	3.50	3.38	3.31	1.32	2.08	0.71
M. olifera	90.24	74.17	54.31	5.70	5.68	6.00	2.74	2.87	6.51	0.76	1.31	0.23
A. indica	59.47	53.53	61.41	5.96	5.36	6.16	10.49	10.36	7.93	2.46	1.36	2.37
M. indica	63.19	68.06	56.71	5.43	5.43	6.73	11.69	11.85	12.32	1.66	2.42	1.20
M. hortensis	36.32	35.90	46.72	6.18	6.23	6.25	4.13	3.99	6.08	0.89	1.11	0.58

P. glabra	55.98	52.28	55.29	6.06	5.58	5.83	5.06	4.97	2.59	0.68	0.42	1.04
P. longifolia	59.58	62.37	72.12	5.95	5.90	6.40	5.91	5.71	5.50	0.72	0.42	0.56
E. jambolana	64.52	75.07	53.14	5.96	5.08	4.66	11.57	11.57	9.36	0.99	1.36	2.60
P. dulce	49.65	42.81	45.17	5.96	6.03	5.66	11.68	11.87	3.13	1.63	1.96	1.20
F. religiosa	71.54	54.01	60.93	7.08	7.3	6.40	8.52	8.29	11.45	0.27	0.45	0.77
F. benghalensis	56.16	56.06	65.50	7.56	7.53	7.70	3.54	3.50	6.24	0.35.	0.46	1.34
T. grandis	54.08	45.83	57.31	5.31	6.15	6.86	4.46	4.29	3.81	1.27	0.89	1.04
E. globulus	54.45	64.89	71.02	5.4	5.66	5.83	10.25	10.37	10.83	0.22	0.26	0.72
F. benjamina	32.08	41.34	70.10	6.85	7.0	7.00	8.84	9.51	8.50	0.13	0.13	1.21
Data represent mean of three replicates. Results are significant at 0.1%(p<0.001)												

(R: Relative water content (RWC); A: Ascorbic acid content; pH; leaf extract pH, T: Total chlorophyll; *winter season)

Table 3a: Biochemical parameters of selected plant species at different sampling sites (SS)*

Species	R (%)			pH			T(mg/g)			A(mg/g)		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
D. regia	62.87	47.75	69.46	6.16	5.92	5.97	2.28	11.8	11.83	1.08	2.91	1.54
T. indica	33.89	62.96	60.27	4.45	3.63	3.40	3.43	3.63	5.97	1.39 1.39	1.24 1.24	0.92
M. olifera	80.60	73.89	70.78	5.85	5.76	5.72	2.76	5.76	13.92	0.85	2.22	0.30
A. indica	56.75	62.92	66.09	6.28	6.07	6.22	10.43	6.07	18.59	2.89	3.10	2.92
M. indica	64.94	67.78	59.55	5.17	5.26	6.77	11.73	5.26	21.05	1.83	3.09	1.22
M. hortensis	38.05	36.04	36.24	6.33	6.33	6.02	4.04	6.33	10.33	0.71	1.09	1.17
P. glabra	57.18	62.04	54.93	6.57	6.21	5.73	5.08	6.21	4.61	0.46	0.39	0.39
P. longifolia	34.26	62.71	66.37	5.77	6.08	5.77	5.81	6.08	9.96	0.69	0.79	0.38
E. jambolana	62.19	72.95	67.23	6.17	4.62	4.67	11.61	4.62	17.58	0.72	1.52	3.22
P. dulce	29.20	38.79	48.82	5.82	6.40	5.76	11.77	6.40	5.33	1.55	1.84	3.27
F. religiosa	52.62	55.35	60.59	7.02	7.65	6.40	8.36	7.65	19.29	0.27	0.37	2.27
F. benghalensis	61.54	70.92	75.03	7.37	7.77	7.67	3.55	7.77	13.10	0.37	0.34	1.15
T. grandis	55.76	55.97	61.24	4.65	4.85	6.85	4.37	4.85	6.83	1.12	2.19	0.42
E. globulus	69.62	73.79	69.62	5.05	5.80	5.63	10.29	5.80	19.08	0.25	0.26	0.64
F. benjamina	45.27	60.08	68.42	6.97	6.91	6.93	9.08	6.91	16.44	0.12	0.12	1.21
Data represent mean of three replicates. Results are significant at 0.1%(p<0.001)												

(R: Relative water content (RWC); A: Ascorbic acid content; pH: leaf extract pH; T: Total chlorophyll; *summer season)

3.2.5 Variation of chlorophyll content during summer season

The total chlorophyll content of selected plant species during summer season was calculated from the values recorded. Among the tree species studied, P.Dulce (11.77 mg g^{-1}) showed higher baseline levels of total chlorophyll and the least value of about 2.28 mg g^{-1} shown by D.regia at site 1. At site 2 the highest and the lowest values exhibited by D.regia (11.8 mg g-1) and T.indica (3.63 mg g-1) respectively. Among the analysed trees at site 3, higher baseline levels of chlorophyll was observed in the leaves of F.religiosa (19.29 mg g-1), and least value was (3.63 mg g-1) recorded in the tree species P.glabra. A considerable significant reduction of chlorophyll content was found in P.dulce at polluted sites compared to the control station during the entire study period. In the plant species such as D.regia, T.indica, M.olifera, M.hortensis, P.longifolia, F.benhalensis, T.grandis and F.benjamia, the total chlorophyll content exhibited higher value in polluted sites than control site. At site 2 the higher value of total chlorophyll content was observed in P.glabra. Among the tree species studied A.indica, M. indica, E. jambolana, F. religiosa, E. globulus and F. benjamina showed higher levels of total chlorophyll content at site 3 that may be due to its tolerant nature.

3.2.6 Changes in ascorbic acid content during summer

Increasing trend was observed in the case of ascorbic acid concentration compared to the control station. At site 2 the highest value was observed in A.indica (2.89 mg g-1) and the lowest concentration of ascorbic acid content of leaves was recorded in F.benjamina (0.12 mg g-1). Tree species F.benjamina (0.12 mg g-1) exhibited the lowest value at S_3. At S_3 among the tree species studied, P.dulce (3.27 mg g-1) exhibited higher concentration followed by E. jambolana (3.22 mg g-1). Plant species M.olifera (0.30 mg g-1) exhibited the least value at site 3. In the present study M.hortensis, P.glabra, E.jambolana, P.dulce, F.religiosa, E.globulus, F.benjamina and A.indica showed elevation in the concentration of ascorbic acid with respect to the control site (S_1). Tree species like D.regia, M.olifera, M.indica, P.longifolia and T.grandis recorded with higher value at site 2 while lower value was observed at site 3 than control site. Trees like F.benhalensis and F. benjamina showed higher value at site 3 and lower value at site 2 compared to the value observed in the control station.

3.2.7 Changes in leaf extract pH

The leaf pH values of the selected plant species during summer season is depicted in Table 3a. The highest and the lowest values of pH observed in F.benhalensis and in T.indica in all the studied sites. Among the studied species, significant reduction in leaf pH was observed in F. benjamina, E.jambolana, P.glabra, M. hortensis, A. indica, M. olifra, T.indica and D.regia with respect to the control station (S_1). The value for leaf pH showed the increasing trend in the plants such as M.indica, P.longifolia, F.benhalensis, T.grandis and E.globulus.

3.2.8 Changes in relative water content

Among the trees studied, high relative water content was estimated in the leaves of M.olifera (80.60 %) and lower value was estimated in P.dulce (29.20 %) at control station (S_1). At site 2 (S_2) tree species M.olifera (73.89 %) was observed with highest RWC and the lowest value was exhibited by M.hortensis (36.04 %). At site 3 the highest and the lowest values exhibited by F.benhalensis (75.03 %) and in M.hortensis (36.24 %) respectively. Specific decrease in the value of relative water content was found in the leaves of M.olifera and in M.hortensis. Studied plant species such as T.indica, A.indica, P.longifolia, E.jambolana, P.dulce, F.religiosa, F.benhalensis, T.grandis, E.globulus, and F.benjamia were observed with increasing trend of moisture content towards polluted sites (S_2 and S_3).

Table 3b: Variation Air Pollution Tolerance Index among the selected sampling sites

Tree	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Winter season															
S_1	7.42	6.60	9.67	10.0	9.17	4.55	6.35	6.82	8.19	7.85	7.58	6.01	6.65	5.80	3.41
S_2	5.69	6.04	8.54	7.49	10.99	4.73	5.68	6.72	9.78	7.79	6.10	6.12	5.52	6.92	4.36
S_3	8.97	5.20	5.72	9.49	7.96	5.38	6.41	7.88	8.97	5.57	7.47	8.42	6.84	8.30	8.89
Summer season															
S_1	7.20	4.48	8.79	10.56	9.59	4.54	6.25	4.23	7.50	5.66	5.68	6.55	6.59	7.35	4.72
S_2	7.96	7.43	20.19	11.78	12.46	4.87	6.68	7.35	9.95	7.04	6.18	7.53	7.99	7.83	6.22
S_3	11.89	6.89	7.68	13.86	9.36	5.55	5.90	7.24	13.91	8.52	11.90	9.89	6.70	8.56	9.69

1:Delonix regia, 2:Tarmarindus indica, 3:Moringa olifera, 4: Azardiracta indica, 5:Mangifera indica, 6:Millingtonia hortensis, 7:Pongamia glabra, 8:Polyalthia longifolia, 9:Eugenia jambolana, 10:Pithecellobium dulce, 11:Ficus religiosa, 12:Ficus benghalensis, 13:Tectona grandis, 14:Eucalyptus globulus, 15:Ficus benjamina.

3.3. Seasonal variation of Air Pollution Tolerance Index

3.3.1 Variation of APTI during winter

The results of Air Pollution Tolerance Index [APTI] calculated for each plant species studied during winter and summer seasons is depicted in Table 3. M.indica among the evergreen trees exhibited the highest APTI value of about 10.9 followed by E.jambolana (9.78). Among the trees studied, lower APTI value of about 4.36 was observed in the leaves of F.benjamina. Air Pollution Tolerance Index (APTI) was calculated for 15 selected plant species growing in Virudhunagar and the data is presented in Table 3. The selected biochemical parameters were analyzed for APTI which plays significant role to determine resistivity and susceptibility of plant species. Ascorbic acid is important in cell wall synthesis, photosynthetic carbon fixation and cell division, pH as an indicator for sensitivity to air pollution, total chlorophyll is also related to ascorbic acid productivity. Air pollution in urban and industrial areas may get adsorbed, absorbed, accumulated or integrated in the plant body and if toxic, may injure them in various ways.[33] Level of injury will be high in sensitive species and low in tolerant ones. Among the tree species studied T.indica (5.20) and M.hortensis (5.38) are sensitive to air pollution. It was also observed that higher tolerance for industrial pollutants shown by Azardiracta indica (9.49) followed by D.regia (8.97) and E.jambolana (8.97).

3.3.2 Variation of APTI during summer

Air pollution tolerance index values were found to be greater in summer than in winter. Among the plants studied, M.olifera (20.1) is considered the most tolerant species at site 2 based on its high tolerance index value and that may be due to high RWC of that species during summer. Ficus religiosa considered as relatively sensitive species for automobile pollutants because of its least tolerance index value (6.18) during summer this may be due to reduction in chlorophyll content and increase in pH value. The presence of the high amount of ascorbic acid and the chlorophyll content also showed the tolerance ability of Mangifera indica and Azardiracta indica. It was observed in the industrial area that the highest tolerance was shown by E.jambolana (13.9) followed by A.indica (13.8). The plant species F.religiosa and M.hortensis can be used as indicators for air pollution at site 2 (S_2) and site 3 (S_3) respectively and that each parameter plays a distinctive role in the determination of the susceptibility of plants. Variation of tolerance of tree species at site 2 (S2) with control area (S_1) suggested that the tree species P.glabra is highly affected by industrial pollutants during summer (6.25- 5.90). Thus, the combination of four biochemical parameters of leaves suggested as representing the best index of the susceptibility levels of plants under field conditions.

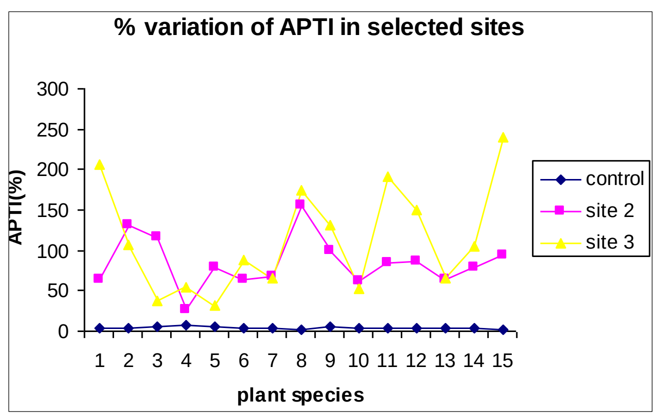


Fig 4: Variation of Air pollution tolerance index among the sites

This study carried out to show the percentage variation of values of polluted sites with control station (S_1). It was showed that the highest variation was exhibited by Polyalthia longifolia (>100%) and least variation recorded in A.indica (26.8%) at site 2 (S_2). It shows P.logifolia was highly affected by automobile pollutants during the study period and the observation was also supported

By Kalyani and Singaracharya, (1995).[11] It was observed from Fig 3 the higher variation of APTI values with control area was observed at S_3 and at S_2 than the values of APTI obtained with S_1 in the tree species F.benjamina (>100 %) and D.regia (>100 %). At the same site 3 the lowest variation was shown by M.indica (32.47 %). This study was also supported by various researchers like Agbaire and Esiefarienrhe (2009) [64].

Table 4: Monthly average API values of control and polluted sites

S. no	Jun '10	Jul '10	Aug '10	Sep '10	Oct '10	Nov '10	Dec '10	Jan '11	Feb '11	Mar11	Apr '11	May '11
1*	21.4	17.9	13.3	13.2	14.3	14.0	14.1	16.3	18.5	20.4	22.3	26
2**	59.9	58.3	54.1	54.9	56.7	55.2	54.0	57.1	58.3	59.4	59.8	62.3

*1(control site) **2 (polluted by automobile exhausts)

The present study is a step in the direction to draw the correlation between Air Quality Index and Air Pollution Tolerance Index of some selected road side trees. Different plant showed considerable variation in their susceptibility to pollution.

Table 5: Mean APTI value of the leaf samples of selected plant species

Plant species	Site 1	Site 2	Site 3
Delonix regia	4.17	6.92	18.77
Tarmarindus indica	12.92	16.53	16.04
Moringa olifera	14.87	20.52	16.70
Azardiracta indica	7.60	19.64	21.67
Mangifera indica	10.54	21.73	18.66
Millingtonia hortensis	4.92	8.80	14.80
Pongamia glabra	13.70	16.18	16.16
Polyalthia longifolia	12.75	17.04	17.56
Eugenia jambolana	14.93	19.87	21.44
Pithecellobium dulce	14.60	17.41	17.04
Ficus religiosa	13.31	16.14	19.67
Ficus benghalensis	03.66	06.82	09.14
Tectona grandis	04.10	06.75	06.74
Eucalyptus globulus	04.12	07.37	08.41
Ficus benjamina	02.73	05.29	09.39

Table 6: Categorization of selected plant species in Virudhunagar town

Plant species	Categorization of plant species		
	Residential	Heavy traffic	Industrial
D. regia	Sensitive	Sensitive	Tolerant
T. indica	Intermediate	Tolerant	Tolerant
M. olifera	Intermediate	Tolerant	Tolerant
A. indica	Tolerant	Tolerant	Tolerant
M. indica	Intermediate	Tolerant	Tolerant
M. hortensis	Sensitive	Intermediate	Intermediate
P. glabra	Intermediate	Tolerant	Tolerant
P. longifolia	Intermediate	Tolerant	Tolerant
E. jambolana	Intermediate	Tolerant	Tolerant
P. dulce	Intermediate	Tolerant	Tolerant
F. religiosa	Intermediate	Tolerant	Tolerant
F. benghalensis	Sensitive	Sensitive	Sensitive
T. grandis	Sensitive	Sensitive	Sensitive
E. globulus	Sensitive	Sensitive	Sensitive
F. benjamina	Sensitive	Sensitive	Sensitive

And at site 3 (S_3) selected plants such as D.regia (18.77), T.indica (16.04), M.olifera (16.70), A.indica (21.67), M.indica (18.66), P.glara (16.16), P.logifolia (17.96), P.dulce (17.04), E.jambolana (21.44), F.religiosa (19.67) became tolerant species and M.hortensisisis is categorized under intermediate category (14.80). F.benhalensis (9.14), T.grandis (6.74), E.globulus (8.41) and F.benjamina (9.39) are categorized as sensitive species. Among the tree species selected A.indica is tolerant at all three observed sites. The tree species T.indica, M.olifera, M.indica, P.glabra, P.longifolia, E.jambolana, P.dulce and F.religiosa form intermediate category at site 1. These tree species became tolerant at site 2 and site 3. D.regia is sensitive species at site 1 and at site 2 and became tolerant at industrial site (S_3). This is due to higher value of chlorophyll content. M.hortensis became intermediate tolerant species at S_2 and S_3 from sensitive category at site1 (S_1). F.benhalensis, T.grandis, E.globulus and F.benjamina showed higher sensitiveness towards pollutants. Based on APTI value, D. regia, was categorized as moderately tolerant species [35]. Out of 15 species studied, 4 species served as indicators of air pollution namely Ficus benghalensis, Tectona grandis, Eucalyptus globulus, Ficus benjamina. Eventhough D.regia is a sensitive species, it becomes tolerant in industrial area.

3.4 Anticipated Performance Index (API) Categorization of plants

Thus, on the basis of this study, the selected trees were assessed into eight categories (Table.5.1). Plants were subjected to a grading scale to determine the anticipated performance of plant species advocated in reference [36]. The highest value scored by F.relogiosa and E.globulus. APTI value for green belt plantation around the polluted area can never be a claim for the removal of air pollutants at the region, but effectively planted trees in the green belt may potentially remove the toxic pollutants in considerable amount [37].

3.5 API gradation of plants

Plant species analyzed for plantation along road sides and in industrial areas were evaluated for various biological socio economic as well as few biochemical parameters including APTI, plant, habit, canopy structure and type of plant [38] was shown in Tables (8-9). It is mentioned in Virudhunagar municipality city corporate cum business plan final report (2008) [39] native tree species would be identified with the help of the forest department and educational institutions. The components identified for improvement are: avenue trees on important roads, planting of trees with tree guards with full coverage of town at road margin and municipal roads, evaluating this tree species for high performance of pollution abatement may be carried out.

Landscape of Virudhunagar consists of a broad-spectrum vegetation. Among the different varieties of tree species in this town, only 15 species are common species. The effect of air pollutants has shown significant effect on vegetation in this town. With the presence of the most sensitive species in a vast area of this town, the amount of pollutants absorbed by the vegetation may get reduced. Further some of the tree species may emit Volatile organic compounds (VOC) which play an important role

In the atmosphere affecting the local air quality. The effect of air Pollution on the plants can be quantified using the parameter, Air Pollution Tolerance Index (APTI).

Table 7: Evaluation of Trees on the basis of some biological and socio-economic characters

Tree species	T.H	C.S	T.T	L.S	L.T	H	E	T
D. regia	+	++	-	-	-	-	-	3
T. indica	++	+	+	-	-	-	++	6
M. olifera	-	-	-	-	-	-	++	2
A. indica	++	++	+	-	-	-	++	7
M.indica	++	+	+	-	+	+	++	8
M.hortensis	-	-	+	-	-	-	-	1
P.glabra	+	+	+	+	+	+	-	6
P.longifolia	-	-	+	+	+	+	-	4
E.jambolana	++	+	+	+	-	+	+	7
P.dulce	++	+	+	-	-	-	+	5
F.religiosa	++	++	+	+	+	+	+	9
F.bengalensis	++	++	+	+	-	+	+	8
T.grandis	+	-	-	++	+	+	+	6
E.globulus	++	+	+	++	-	+	++	9
F.benjamina	++	++	+	+	-	+	+	8

T.H: Tree habit, C.S: Canopy structure, T.T: Type of tree, L.S: Laminar size, L.T: Laminar Texture, E: Economic importance, H: Hardness, T: Total plus

Table 8: Anticipated performance index (API) of studied plant species in polluted area1

Name	APTI Grade	*S.E Grade	Total plus	% scoring	API Grade	Assessment category
D. regia	-	3	3	19	0	Not recommended
T. indicia	2	6	8	50	2	Poor
M. olifera	3	2	5	31	1	Very poor
A..indicia	2	7	9	56	3	Moderate
M.indicia	3	8	11	69	4	Good
M.hortensis	-	1	1	6	0	Not recommended
P.glabra	2	6	8	50	2	Poor
P.longifolia	2	4	6	38	1	Very poor
E.jambalona	2	7	9	56	3	Moderate
P.dulce	2	5	7	44	2	Poor
F.religiosa	2	9	11	69	4	Good
F. Bengalensis	-	8	8	50	2	Poor
T.grandis	-	6	6	38	1	Very poor
E.globulus	-	9	9	56	3	Moderate
F.Benjamina	-	8	8	50	2	Poor

* Socio Economic Grade

Table 9: Anticipated performance index (API) of studied plant species in polluted area2

Name	APTI Grade	*S.E Grade	Total plus	% scoring	API Grade	Assessment category
D. regia	2	3	5	31	1	Very poor
T. indica	2	6	8	50	2	Poor
M.olifera	2	2	4	25	0	Not recommended
A.indica	3	7	10	63	4	Good
M.indica	2	8	10	56	3	Moderate
M.hortensis	1	1	2	13	0	Not recommended
P.glabra	2	6	8	50	2	Poor
P.longifolia	2	4	8	38	1	Very poor
E.jambolana	3	7	10	63	4	Good
P.dulce	2	5	7	44	2	Poor
F.religiosa	2	9	11	69	4	Good
F.bengalensis	-	8	8	50	2	Poor
T.grandis	-	6	6	38	1	Very poor
E.globulus	-	9	9	56	3	Moderate
F.benjamina	-	8	8	50	2	Poor

* Socio Economic Grade

The table 2 shows the parameters used to grade the performance of a particular tree species. 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. Table 1 shows the assessment categories along with the scores. It can be shown from the table 7, even though APTI of the species is negligible, but still the socio-economic score of some tree species is reasonably high. Species like E.globulus and F.benhalensis secured reasonable SE grade. But they are sensitive species according to APTI grade. Table 9 shows the API of the studied plant species. APTI value of the selected plant species in the heavy traffic area together with socio economic grade were also considered for this assessment. According to this table, tree species such as M.indica and F.religiosa are assessed under category good to grow in the areas polluted by automobile emissions. Tree species like T.indica, P.glabra, P.dulce, F.benhalensis and F.benjamina are very poor to grow along road sides.

Out of 15 species studied, the economic and aesthetic value of this tree is well known and it may be recommended for the extensive planting as a first curtain. Also, Dali mondal (2011) [73] Categorized Ficus religiosa as the good performer even in the presence of air pollutants. Among the 15 species studied, 4 species could not be pollution sink because they are assessed as very poor categories in both industrial and heavy traffic areas. Mangifera indica and Ficus relogiosa are scored 69 % and it was assessed under the category good for planting in heavy traffic areas and road sides.

4. Conclusion

It can be concluded that due to the increasing pollution load on the plants, the vegetation in the town is under extreme stress. To ensure that the generated pollution load is removed from the atmosphere, the In Virudhunagar area workers are facing so many health problems as they were exposed to toxic fumes from industries. So, this study is useful for the selection of suitable plant species (with high API grade) for plantation around industrial area. It was categorized as good (% scoring 69) for planting Ficus religiosa and Eugenia jambolana in areas around industries (Table 9). Even though Delonix regia possesses high APTI value, it could not score a reasonable API. Quantification of the effect of the pollutants on the tree species should be made at regular intervals. This study indicates M.indica and F.religiosa are the suitable plants to plant a long road sides. It also indicates A.indica and E.jambolona are suitable for planting around industrial areas among the 15 commonly growing tree species studied in Virudhunagar.

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