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RESEARCH ARTICLE

Evaluation of anticipated performance index of some plants species for green belt development in an industrial area

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SUMMARY

In the present study, the air pollution tolerance index (APTI) of six plant species collected from a residential, traffic and industrial area have been evaluated by analyzing important biochemical parameters. On the basis of air pollution tolerance index and some biological and socio economic parameters of plants, the anticipated performance index (API) of these plants were calculated. Among all the plants taken under consideration, *Azadiratca indica* and *Delonix elata* were classified into the good category. The most suitable plants species for green belt development in urban areas were identified and recommended. For green belt development it is necessary that plants used for green belt must be tolerance towards air pollution. Green belts are effective tools for mitigation of air pollution.

Key Words : Green belt, Air pollution, Anticipated performance index (API), Air pollution tolerance index (APTI), Biochemical parameters

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Urban areas of many developing countries are suffering from various environmental problems arising from over population and lack of enough public facilities. Air pollution is one of the major problems in these areas. Air pollution control is more complex than most other environmental challenges. No physical or chemical method is known to ameliorate aerial pollutants. A suitable alternative may be to develop a biological method by green plants in and around industrial and urban areas (Agarwal, 1988; Santra, 1995; Thakre, 1995; Shannigrahi *et al.*, 2003; Sivasamy and Srinivasan, 1996; Fukuoka, 1997; Ghose and Majee, 2001). Plants, the main green belt (GB) component act as a sink and as living filters to minimize air pollution by absorption, adsorption, detoxification, accumulation and for metabolization without sustaining serious foliar damage or decline in growth, thus, improving air quality by providing oxygen to the atmosphere (Sharma *et al.,* 1994; Rawat and Banerjee, 1996; Beckett *et al.*, 1998). Plants differ markedly in their responses to pollutants, some differ markedly in their responses to pollutants, some being highly sensitive and others hardy and tolerant(Singh and Rao, 1983; Sarala *et al.*, 2009).

An important factor in developing investigation, belt is that different plant species have a varying degree of sensitivity towards a particular stress or they can be categorized into 'sensitive' and 'tolerant'. Under the present investigation stress tolerant species (air pollution) were experimented from the study area. Since tolerant species can be used for green belt development. Tolerant plant species can function as pollution sink and therefore, a number of environmental benefits can be derived by planting tolerant species in affected areas (Rao *et al.*, 2004).

The evaluation of the tolerance level of plant species towards air pollution from leaf parameters requires empirical data used for calculation of the air pollution tolerance index (APTI), an index developed by Singh and Rao (1983). The parameters used in defining sensitivity or resistance of plants towards different air pollutant concentration are

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ascorbic acid content (Keller and Schwager, 1977), relative water content (RWC), leaf extract pH (Chaudhary and Rao, 1977) and peroxide activity (Eckert and Huston, 1982). The APTI is based on four biochemical properties of leaves such as ascorbic acid, total chlorophyll, relative water content and leaf extract pH. Plant sensitivity and tolerance to air pollutants vary with these parameters.

The present study is the selection of plant species which are grown around industrial urban areas in India. Plants differ considerably with reference to their responses towards pollutants. Some being highly sensitive and others hardly and tolerant. On the basis of the APTI some relevant biological and socio economic characters the anticipated performance index (API) of various plant species was determined for GB development.

MATERIALS AND METHODS

Selection of sampling area and sampling details:

The research work was mainly confined in Dindigul town Tamil Nadu. The ambient air quality status of this town at three sampling stations that is the average concentration (µg / m³) of SO_2, NO_x, SPM (Suspended particulate matter) are given in the Table A.

Table A : Selection of sampling area and sampling details

Bio indicators sations	Pollutants (µg / m³)			
	Seasons	SPM	SO_2	NO_x
Station no:1(Residential)	Winter	111.2	11.4	32
	Summer	99.4	9.5	33.3
Station no: 2(Traffic)	Winner	158.4	15	25.6
	Summer	147.6	18.7	29.7
Station no: 3(Tannery)	Winter	98	14.2	20
	Summer	65.5	9.9	14.7

Six plants species were selected from residential, industrial and traffic area of Dindigul town. The screening and selection of the plant species was partly based on literature survey of similar work and guidelines of central pollution control Board (2000). The six plant leaf samples were collected at the lower most position of canopy at a height of 6.7 ft from the ground surface. Samples were cleaned with distilled water and then refrigerated (22°C) under suitable condition for further biochemical analysis.

Biochemical analysis of plants :

Ascorbic acid:

The ascorbic acid content of leaf sample was determined with the help of a Spectrophotometer. Ascorbic acid content was calculated by the formula given by Keller and Schwager (1977).

$$\text{Ascorbicacid}(\text{mgg}^{-1}\text{freshweight}) = (E_0 - E_s - E_t)V/W * 100) * 100$$

Where,

V is the volume of the extract, W is the weight of the leaf sample (g) and E_0, E_s and E_t are optical densities of blank sample, plant sample and sample with ascorbic acid, respectively.

Photosynthetic pigments :

Pigment content was computed applying the following formulae given by Maclachlan and Zalic (1963) for chlorophyll 'a' and 'b'.

$$\text{Chl a} = (12.3\,D_{663} - 0.86\,D_{645}\ V / 1000\ W) * 100$$

$$\text{Chl b} = (19.3\,D_{645} - 3.6\,D_{663}\ V / 1000\ W) * 100$$

Leaf extract pH :

0.5 g of leaf sample was crushed and homogenized in 50 ml deionized water, then the mixture was centrifuged and supernatant was collected for detection of pH by a digital pH meter.

Relative water content :

The relative water content (RWC) in percentage was calculated by using the formula given by Sen and Bhandari (1978).

$$\text{RWC} = (\text{fresh weight dry weight/turgid weight - dry weight}) * 100$$

Calculation of air pollution tolerance index of plants (APTI):

Ascorbic acid content, leaf extract pH, total chlorophyll content and relative water content were taken into account in the form of a mathematical expression to obtain an empirical value, signifying their APTI.

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

where,

A is the ascorbic acid content in mg g^{-1} of fresh water, T is the total chlorophyll in mg g^{-1} of fresh weight. P is the pH of leaf extract, and R is the relative content of water, in percentage. Based on the development and evaluation of APTI values among the samples they were categorized into three groups, namely < 10 is sensitive species, > 10 – 16 is inter mediate species and > 17 is tolerant species.

For determining which plant species are most suitable for the development of green belts, calculation the anticipated performance index (API) was needed. All six plants selected for green belt development were evaluated in terms of their API. The API values were calculated by using various biological and socioeconomic, as well as some biochemical characteristics, such as APTI, plant habit, canopy structure and economic value (Table B). The method to calculate API value is given in the Table B. Based on this pattern grading of six plant species, promising plants were recommended for green belt development.

Table B : Gradation of plant species on the basis of air pollution tolerance index (APTI) and other biological and socio economic characters

Grading characters		Pattern of assessment	Grade allotted
(a) Tolerance	APTI	9.0 - 12.0	+
		12.1 - 15.0	++
		15.1 - 18.0	+++
		18.1 - 20.0	++++
		20.1 - 24.0	+++++
(b) Biological	Plant habit	Small	-
		Medium	+
		Large	++
	Canopy structure	Sparse/irregular/globular	-
		Spreading crown/open/semi- dense	+
		Spreading dense	++
	Type of plant	Deciduous	-
		Evergreen	+
laminar structure	Size	Small	-
		Medium	+
		Large	+
	Texture	Smooth	-
		Coriaceous	+
	Hardiness	Delineate	-
		Hardy	+
(c) Socioeconomic	Economic value	Less than three uses	-
		Three or four uses	+
		Five or more uses	+

Statistical analysis :

Linear regression analysis was performed between independent variables such as chlorophyll, leaf extract pH, relative water content (RWC) ascorbic acid and dependent variables such as APTI by using XLSTAT (version 10) software. These scatter plots illustrated the degree of correlation (R^2) between the said variables.

RESULTS AND DISCUSSION

The findings of the present study well as relevant discussions have been presented under following heads:

APTI results :

All six plants selected for green belt development were evaluated for biological as well as some biochemical characteristics, including APTI, plant habit, canopy structure and economic value. The grading of six plant species is shown in Table 1. Plants fitting into the grading pattern with respect to their anticipated performance index (API) were recommended for green belt development.

API results :

Using the API score categories provided in Table 1, scores of different selected plants (Table 3) revealed that *Azadiracta Indica* and *Delonix elata* were good performers, while the remainder of the plant Species such as *Moringatinctoria*, *Calotrophis*, *Thyme rosemary* and *Cyandon dactylon* were poor performers.

Table 1 : Anticipated performance index

Grade	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

Discussion on experimental result of biochemical parameters:

Plants have been categorized into groups according to their degree of sensitivity towards and tolerance of various air pollutants on the basis of experimental and available data (Kagamimori *et al.,* 1978; Bhattacharya, 1983;Khan and Abbasi, 2002). Levels of tolerance of air pollution vary from species to species depending on the capacity of plants to withstand the effect of pollutants without showing any external damage.

APTI is a unique index because it incorporates four different biochemical parameters such as total chlorophyll content (in mg g^{-1} fresh weight), pH of leaf extract, ascorbic acid and relative water content. The APTI has been determined for six plant species (Table 2).

As shown in Table 2 in the residential area the highest total chlorophyll content (mg g^{-1} f.wt) was recorded in *Moringa tinctoria* (0.948 mg / g) followed by *Azadiratca indica,* (0.85 mg / g), *Thymerosemary* (0.80 mg / g), *Calotrophis* (0.674 mg / g), *Cyandon dactylon* (0.66 mg /g) and *Deloxin elata* (0.531 mg /g). In the traffic area the highest mean total chlorophyll content was recorded in *Moringa tinctoria* (0.636 mg / g) followed by *Azadiratca indica,* (0.478 mg /g), *Calotrophis* (0.47 mg /g), Thymerosemary(0.458 mg /g), *Cyandon dactylon* (0.42 mg /g) and *Delonix elata*(0.384 mg / g) . In industrial area the highest mean total chlorophyll content was recorded in *Delonix elata*(0.76 mg / g) followed by *Azadiratca indica* (0.69 mg /g), Thymerosemary(0.56 mg / g), *Moringa tinctoria* (0.48 mg / g), *Calotrophis* (0.43 mg / g) and *Cyandon dactylon* (0.37 mg /g) . A considerable loss in total chlorophyll in the leaves of plants exposed air pollution stress supports the argument that the chloroplast is the primary site of attack by air pollutant and such as SPM, SO_2 and NO_X . Air pollutants make their entrance into the tissues through the stomata and cause partial denaturation of the chloroplast and decrease pigment content in the cells of polluted leaves (Rao and Leblanc, 1966). High amount of gaseous SO_2 causes destruction of chlorophyll and that might be due to the replacement of Mg^{2+} by two hydrogen atoms and degradation

Table 2 : Biochemical parameters along with APTI of the leaf samples units are expressed as mg/g fresh weight except pH and RWC content which is expressed in units and percentage respect

Name of the plant species	Sampling station (Residential) pH	RWC	Chl	AA	APTI	Sampling station (Traffic) pH	RWC	Chl	AA	APTI	Sampling station (Tannery) pH	RWC	Chl	AA	APTI	APTI average
Azadiracta indica	5.85	62.8	0.85	2.08	7.673	5.55	65	0.478	4.052	8.941	5.78	75	0.69	2.62	9.195	8.603
Delonix elata	7.53	65.3	0.531	2.65	8.66	9.65	55.3	0.384	3.58	9.08	6.92	79	0.76	3.15	10.31	9.35
Moringa tinctoria	6.75	72.05	0.948	1.65	8.475	5.5	62.5	0.636	3.55	8.428	7.2	82	0.48	3.68	11.02	9.307
Calotrophis	7.6	70.5	0.674	2.56	9.168	4.56	58.5	0.47	3.65	7.68	8.52	86.5	0.43	1.89	10.34	9.062
Thyme rosemary	5.24	72.3	0.8	1.96	8.41	4.85	62.5	0.458	2.35	7.49	5.2	72.5	0.56	1.08	13.5	9.8
Cyandon dactylon	6.35	75.6	0.66	3.88	10.27	3.65	56.5	0.42	4.56	7.5	6.6	77.5	0.37	2.34	9.38	9.05

Table 3 : Evaluation of plant species based on their APTI values and some biological and socioeconomic characters

Sr.No.	Name of the plant species		APTI	Tree habit	Canopy structure	Type of tree	Laminar		Economic importance	Hardiness	Grade allotted		API grade
							Size	Texture			Total plus (+)	% Scoring	
1.	*Azadiracta indica*	R	7.67								11	68.75	4
		T	8.94								11	68.75	4
		I	9.19								11	68.75	4
2.	*Delonix elata*	R	8.66								10	62.5	4
		T	9.08								10	62.5	4
		I	10.31								10	62.5	4
3.	*Moringa tinctoria*	R	8.47								[illegible]	31.25	1
		T	8.42								[illegible]	31.25	1
		I	11.02								[illegible]	31.25	1
4.	*Calotrophis*	R	9.16								7	43.75	2
		T	7.68								7	43.75	2
		I	10.34								7	43.75	2
5.	*Thymerosemary*	R	8.41								6	37.5	1
		T	7.49								6	37.5	1
		I	13.5								6	37.5	1
6.	*Cynadon dactylon*	R	10.27								4	25	0
		T	7.5								4	25	0
		I	9.3								4	25	0

of chlorophyll molecules to phaeophytin (Rao and Leblanc, 1966).

The mean value of pH at the residential area for all six plant species ranged from 5.24 of *Thyme rosemary* to that of *Calotrophis* 7.60. At traffic area, *Delonix elata* had the highest pH value 9.65 and the lowest pH value *Cyandon dactylon*(3.65). In the industrial area, *Calotrophis* had the highest pH value and the minimum was shown by *Thymerosemary* (5.20). The low pH of the leaf extract showed a relationship with the type of air pollution. The more acidic nature demonstrates that the air pollutant mostly gaseous types namely SO_2, NO_X diffuse and form acid radicals in the leaf matrix by reacting with cellular water. This further effect the chlorophyll molecules (Turk and Wirth, 1975). A pH on the higher side improves tolerance against air pollution (Agarwal, 1986).

In residential area, the relative water content of *Cyandon dactylon* was maximum (75.06) followed by *Azadiratca indica,* minimum (62.8). In the traffic area the relative water content was maximum for *Azadiratca indica,* (65.0) and the minimum for *Delonix elata*(55.3). In industrial area the relative water content was maximum for *Calotrophis* (86.5) and the minimum for *Thymerosemary* (72.8). The relative water content (RWC) indicates change in leaf matrix hydration condition and will generate higher acidity condition when RWC is low. The RWC also helps to maintain physiological balance under stress condition and higher relative water content is advantageous for drought resistance in plants (Dedio, 1975).

In residential area the highest content of ascorbic acid was found in *Cyando dactylon* (3.88 mg /g) followed by *Delonix elata*(2.65 mg / g), *Calotrophis* (2.56 mg / g). *Azadiratca indica,* (2.08 mg / g), *Thymerose mary* (1.96 mg /g) and *Moringa tinctoria* (1.65 mg / g).In traffic area the highest content of ascorbic acid was found in *Cyandon dactylon*(4.56 mg /g) followed by *Azadiratca indica,* (4.05 mg / g), *Calotrophis*(3.65 mg /g), *Delonix elata* (3.58 mg / g), *Moringa tinctoria* (3.55 mg / g) and *Thymerosemary* (2.35 mg /g). In industrial area the highest content of ascorbic acid was found in *Moringa tinctoria* (3.68 mg /g), *Delonix elata*(3.15 mg /g), *Azadiratca indica,*(2.62 mg /g), *Cyandon dactylon*(2.34 mg /g), *Calotrophis* (1.89 mg /g) and *Thymerosemary* (1.08 mg / g).Comparing the ascorbic acid content between residential, traffic and industrial area all the six plants species showed increasing trend from residential area to traffic area. *Azadiratca indica*, *Delonix elata* and *Moringa tinctoria* showed the increasing trend from residential area to industrial area but the decreasing trend was shown by plant species such as *Calotrophis*, *Thymerosemary* and *Cyandon dactylon*. Ascorbic acid is an antioxidant which is found in the growing parts of plants and influences the resistance to adverse environmental condition, including air pollution (Keller and Schwager, 1977). Soil contamination and air pollution have been found to result in a decrease in leaf ascorbic acid content in exposed Tibouchina pulchra saplings (Klumpp *et al.,* 2000). Together with mineral deficiencies, these are among the factors responsible for the formation of reactive oxygen species (ROS) (Hippeli and Elstner, 1996). Earlier research proved that ascorbic acid decrease ROS concentration in leaves. An increased level of ascorbic acid in leaves will increase air pollution tolerance in plants (Chaudhary and Rao, 1977). Higher chlorophyll content in plants might favour tolerance to pollutants (Joshi *et al.*, 1993).

Scatter plot interpretations :

Fig. 1, 2 and 3 showed the linear regression plots of individual variables with APTI. The correlation between APTI and four biochemical parameters revealed that there exists a positive relation to each other. It was observed at residential area a high positive correlation between APTI and relative water content (RWC) (r=0.5519) and ascorbic acid (r=0.7451). In traffic area there existed positive correlation between APTI and pH (r=0.6127). In tannery area all the variables with APTI showed positive correlation but not significant.

Scatter plot of various biochemical parameters with APTI values.

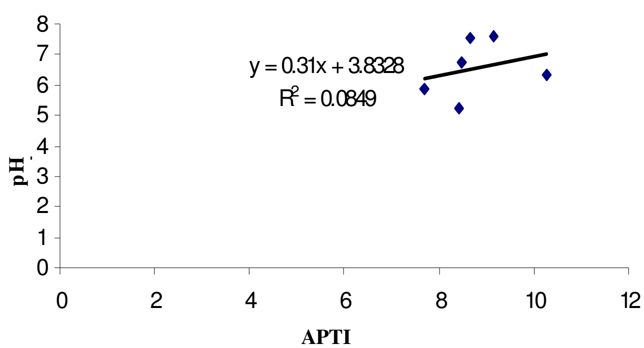

Fig. 1a : Regression between APTI and pH at residential area

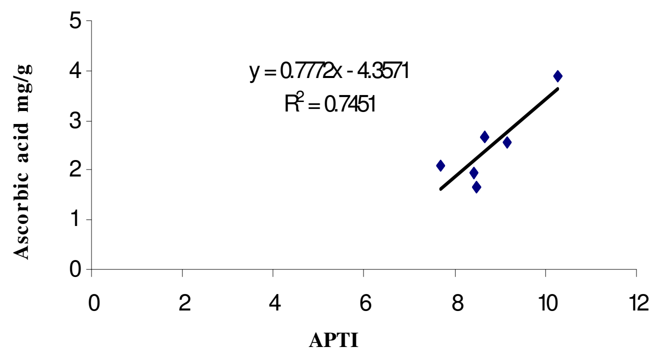

Fig. 1d : Regression between APTI and ascorbic acid mg/g at residential area

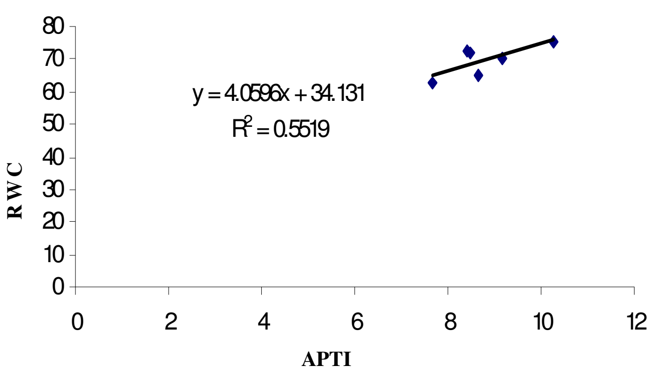

Fig. 1b: Regression between APTI and RWC at residential area

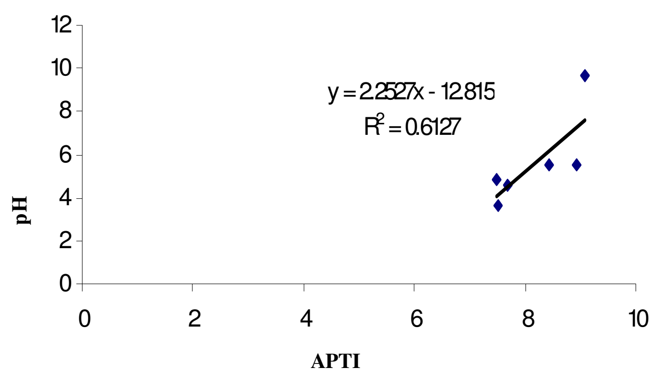

Fig. 2a: Regression between APTI and pH at traffic area

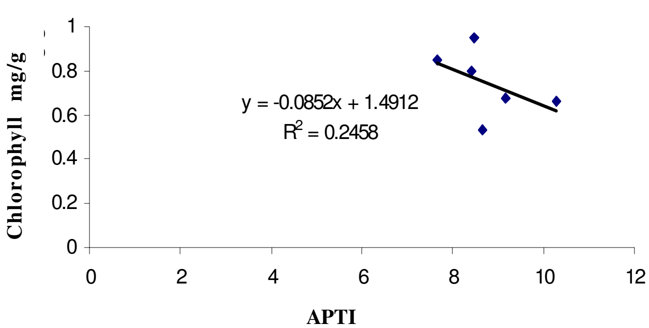

Fig. 1c : Regression between APTI and chlorophyll mg/g at residential area

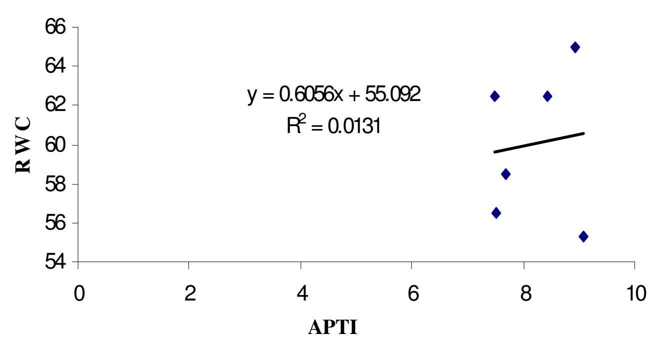

Fig. 2b: Regression between APTI and RWC at traffic area

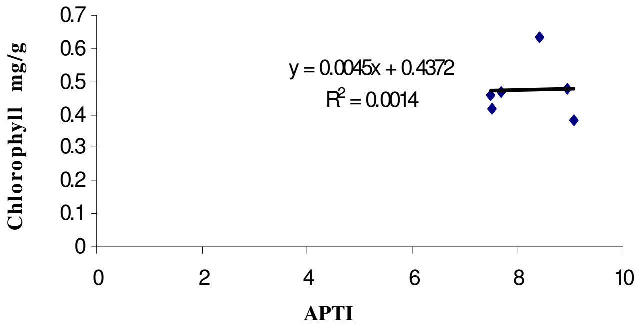

Fig. 2c: Regression between APTI and chlorophyll mg/g at traffic area

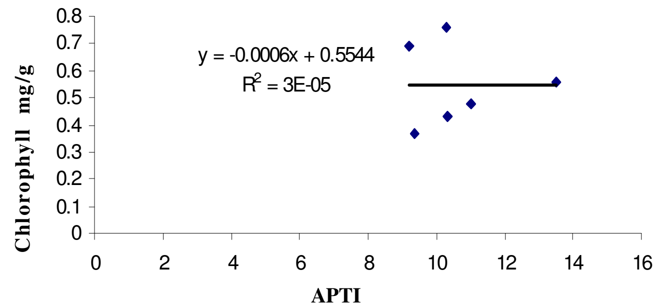

Fig. 3c : Regression between APTI and chlorophyll mg/g at tannery area

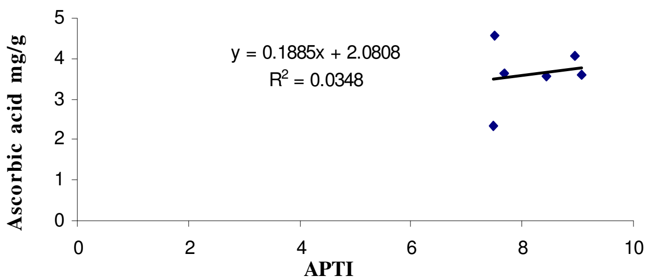

Fig. 2d : Regression between APTI and ascorbic acid mg/g at traffic area

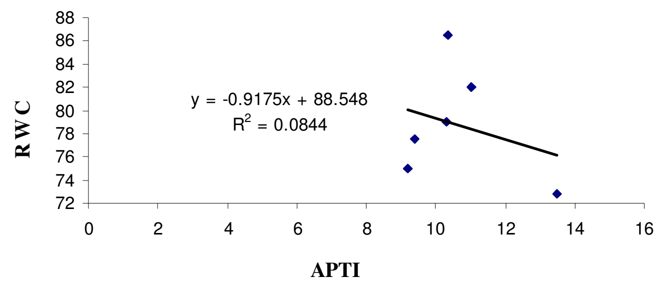

Fig. 3b : Regression between APTI and RWC at tannery area

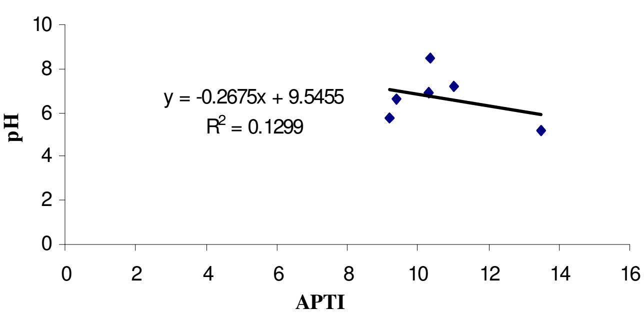

Fig. 3a : Regression between APTI and pH at tannery area

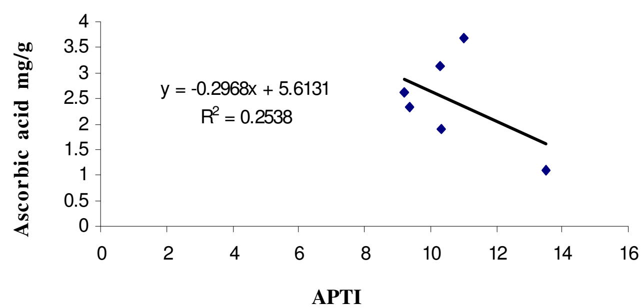

Fig. 3d : Regression between APTI and ascorbic acid mg/g at tannery area

Anticipated performance index (API) of plant species in a green belt (GB) plantation :

Plant species for plantation in industrial urban areas were evaluated for various biological and socio-economic as well as a few biochemical characteristics, *viz.,* APTI, plant habit, canopy structure, type of plant, laminar structure and economic value. These parameters were subjected to a grading scale to determine the anticipated performance of plant species as advocated in reference (Singh and Rao, 1983). The grading pattern of six plant species evaluated in Table 3 and which fit into the grading pattern with respect to their anticipated performance index (API) were recommended (Table 4) for plantation in an industrial/urban area. A comparison of the assessment parameters with respect to grading characters using a multiplication or summation of the anticipated performance of plant species found those parameters to be quite similar. Table 4 showed that out of six species, *Azadiratca indica* and *Delonix elata* were the most tolerant plant to grow in industrial areas and can be expected to perform well. It has a dense plant canopy of evergreen like foliage, which may afford protection from pollution stress. The economic and aesthetic value of this tree is well known and it may be recommended for extensive planting as a first curtain. *Moringa tinctoria*, *Calotrophis*, *Thyme rosemary* and *Cyandon dactylon* besides these two good performing species, four were found to be unsuitable as a pollution sink because of their lower anticipated performance but have been planted in industrial areas for their aesthetic value and other economic uses. The latter species are attractive plants that certainly enhance the aesthetic value of the industrial/urban areas. Thus, an evaluation of anticipated plant performance might be very useful in the selection of appropriate species.

Table 4 : Anticipated performance index (API) of studied plant species

Sr. No.	Name of the plant species	Grade alloted	API %	Assessment	
1.	*Azadiratca indica,*	11	68.75	4	good
2.	*Delonix elata*	10	62.5	4	good
3.	*Moringa tinctoria*	5	31.25	1	very poor
4.	*Calotrophis*	7	43.75	2	poor
5.	*Thymerosemary*	6	37.5	1	very poor
6.	*Cyandon dactylon*	4	25		Not recommended

Conclusion :

The present study indicates *Azadiratca indica,* and *Delonix elata* were judged to be in the good category and were recommended for plantation. These plants were the most tolerant plant to grow in industrial areas and can be expected to perform well for the development of green belt.

To abate the impact of pollutants, environmentalists and decision makers have long been emphasizing the need for a "Perennial green envelop" in and around urban areas as well as long road sides. Green belts provide one of the natural ways of cleaning the atmosphere by absorption, reflection, diffusion of gaseous and particulates pollutants and of noise through their leaves which act as efficient pollutant trapping device, plants have a very large leaves which act as efficient pollutant trapping devices.

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