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RESEARCH ARTICLE

EVALUATION OF ANTICIPATED PERFORMANCE INDEX OF SOME TREE SPECIES OF ROHTAK CITY HARYANA, INDIA

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ABSTRACT

The present study was designed to evaluate the variation of biochemical characteristics and air pollution tolerance index (APTI) of 15 selected tree species growing at industrial, residential and campus sites of Rohtak City, Haryana, and North India. So as to evaluate the susceptibility level of plants to air pollutants five parameters namely leaf extract pH, relative water content, ascorbic acid, chlorophyll and proline were determined and synchronized together to laying down the air pollution tolerance index (APTI) of fifteen frequently grown tree species around Rohtak city, Haryana. In the present study, the air pollution tolerance index (APTI) of many tree species has been systematized by analyzing important biochemical parameters. The anticipated performance index of *F.virens* and *E.obliqua* tree 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 tree species are *F.virens* and *E.obliqua* in green belt areas are identified and recommended for long term air pollution management.

INTRODUCTION

Air pollution is anthropogenic introduction of chemicals, biological materials or particulate matter which includes SOx, NOx, CO and soot particles as well as smaller quantities of toxic metals, organic molecules and radioactive isotopes into the atmosphere that can cause damage to living organisms or humans or ruin the environment (Anonymous, 2008; Bhattacharya *et al*, 2013; Chouhan *et al*, 2011). It can also be regarded as the inconstancy or variation in the atmospheric constituent concentration that would have been existed without any human intervention. Due to the industrial growth we are becoming so much concerned and possessed as our natural environment has undergone many bifurcations and diversions (Adamsab *et al*, 2011; Seyyednjad *et al*, 2011). Many urban and industrial sites and the surrounding regions worldwide are affected by decline of air quality which is a major environmental problem (Kuddus *et al*, 2011). In spite of several efforts done for environmental restoration in India it still appears to be a dreadful task. Vegetation is considered as one of the excellent and natural way of cleaning the atmosphere by implementing an enormous leaf area for impingement, accumulation and absorption of air pollutants in the environment with a several extent (Escobedo *et al*, 2008; Das, 2010).

Air pollution reduction is considered as the most compelling challenge that leads to integrable attempts. Remediation and monitoring of air pollution can be done by evaluating the tolerance ability of plants to air pollution. Urban air pollution can be prevented by variety of ways. One of the impressive and well recognized ways for the recovery of environment and reduction of pollution is planting of trees and shrubs throughout the world (Agbaire and Esiefarienrhe, 2009). The resistance and susceptibility of plants can be determined by evaluating the physiological and biochemical parameters (Agbaire, 2009; Enete and Ogbonna, 2012). Both developed and developing countries are affected with serious urban air pollution problem that leads to adverse effects on environment and on living organisms (Rai, 2011a, by, 2013) between b and 2013. Emission of air pollutants at the source cannot be checked completely by any device chemically or mechanically. After the release of pollutants in to the atmosphere only plants can be helpful in adsorbing and metabolizing them from the atmosphere therefore plants serves as a very important role in reducing air pollution and also helps in improving the quality of air by taking up gases and particles (Hoque *et al*, 2007; Joshi and Swami, 2009; Horaginamani and Ravichandran, 2010). For various air borne particles in the atmosphere plants can serves the role of scavengers (Seyyednejad *et al*, 2011). Trees also serves as the air pollutant sink to reduce the concentration of air pollutants in the air. Therefore this function will be suitably performed by pollution tolerant species (Prajapati and Tripathi, 2008; Miria and Khan, 2013).

By calculating an index known as air pollution tolerance index (APTI) based on four bio-chemical and physiological parameters viz. chlorophyll, ascorbic acid, potential of hydrogen ion concentration of leaf, relative water content the tolerance level of the plants can be evaluated (Singh and Rao 1983; Dwivedi *et al*, 2008). When this tolerance index of plants combines with some of the socioeconomic and biological characters the anticipated performance index (API) was also determined which gives more stable results than those with single parameter. Therefore the purpose of this study is to establish the susceptibility level of different tree species by determining the variation in biochemical parameters with reference to their tolerance and performance index for the selection of appropriate species which can be expected to perform well for the development of green environment of Rohtak city, Haryana.

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METHODS AND MODHODS

Study area

Rohtak is one of the districts of Haryana state and known as the “City of Dairies” and “Heart of Haryana”. It is situated in the northern region of India. It is located (28.8909ºN 76.5796ºE) 70 km northwest of New Delhi and forms a part of NCR with an elevation of 214 m above mean sea level (AMSL). Total geographical area of the city is 1668.47 km^2 with the total population of 1058683 as per 2011 census. Average annual rainfall of Rohtak is 458.5 mm. The climate of Rohtak has extreme variations in temperature.

Sampling sites and sampling procedure

Sites selected for sampling were the Industrial area of Asian paints and LPS, Residential area of Sector 2 and 3 and Campus area of Maharishi Dayanand University, Rohtak used as the control area to compare the pollution load in different sites. The geographical location of campus (M.D university, Rohtak) is 28°52'37"N 76°37'1"E Residential (sector 2) 28°53'39"N 76°38'10"E (sector 3) 28°53'52"N 76°37'43"E and Industrial area (Asian paints) 28°52'11"N 76°40'23"E and (LPS) 28°53'39"N 76°32'59"E.

Leaf samples of selected fifteen tree species *F. benghalensis*, *F. religiosa*, *A. indica*, *Syzygium cumini*, *Saraca asoca*, *F. benjamina*, *Mangifera indica*, *A. scholaris*, *B. variegate*, *E. obliqua*, *A. lebbeck*, *P. guajava*, *Z.mauritiana*, *F.virens*, *P. glabra* of different sites were collected from the study area during the period of February to April 2014. Precautions were taken while taking the samples such as leaves were not plucked alone but taken out along with the twigs for the identification purpose. The tree species were stored in the polythene bags to retain the moisture level and keep away the dryness. The leaf fresh weight was taken immediately upon getting to the laboratory. Then the leaf samples were preserved in the refrigerator at 4°C for biochemical analysis. Visible biochemical effects were recorded in every tree species of Rohtak city.

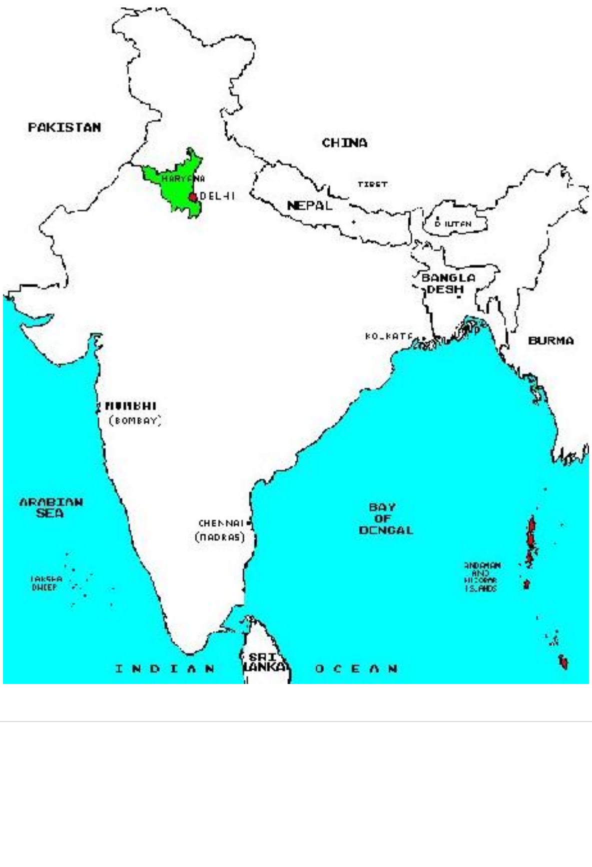


Fig 1 Satellite view of Rohtak city, Haryana, India

METHODOLOGY

Analytical methods such as Ascorbic acid were determined by the method used by Bajaj and Kaur (1981). Total chlorophyll in the leaves of selected tree species of different sites was determined by Arnon (1949). Potential of the hydrogen ion concentration of the leaf was determined by Agbaire and Esiefarenrhe (2009). Leaf related water content was determined by using the method of Singh (1997). Proline content of selected tree species was determined by the method of Bates *et al*, (1973).

Air pollution tolerance index (APTI)

Air pollution tolerance index was determined by Singh and Rao (1983) to assess the tolerance/resistance power of plants against air pollution.

The formula used to calculate the Air pollution tolerance index was as follows;

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

Where,

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

Air Pollution Tolerance index range:

< 1 =Very Sensitive,

1 to 16 = Sensitive,

17 to 29 = Intermediate
30 to 100 = Tolerant (Kalyani and Singaracharya, 1995).

Anticipated performance index (API)

By combining the resultant APTI values with some relevant biological and socio-economic characters (plant habit, canopy structure, type of plant, laminar structure and economic value), the API was calculated for different species.

Table 1 Gradation of tree species on the basis of air pollution tolerance index (APTI) and other biological and socio-economic characters

Grading	Character	Pattern Of Assessment	Grade Allotted
Tolerance	APTI	12.0 – 16.0	+
		16.1 – 20.0	++
		20.1 – 24.0	+++
		24.1 – 28.1	++++
		28.1 – 32.0	+++++
		32.1 – 36.0	++++++
Biological and socio-economic	TH	Small	-
		Medium	+
		Large	++
	CS	Sparse/irregular/globular	-
		Spreading crown	+
		Spreading dense	++
	TOP	Deciduous	-
		Evergreen	+
	Laminar structure	Small	-
		Medium	+
	Size	Large	++
	Texture	Smooth	-
		Coriaceous	+
	Hardiness	Delineate	-
		Hardy	+
	EV	Less than three uses	-
		Three or four uses	+
		Five or more uses	++

APTI: Air pollution tolerance index, **TH:** Tree habitat, **CS:** Canopy Structure, **TOP:** Type of plant, **EV:** Economic value

Based on these characters, different grades (+ or) are allotted to plants. Different plants are scored according to their grades.

Statistical analysis

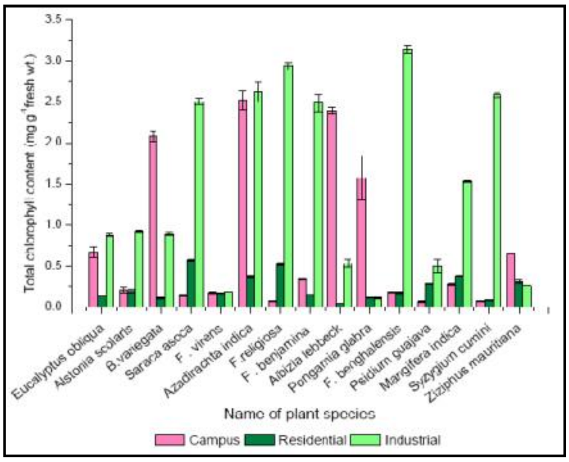
All data were presented as mean of three replicates, ± standard deviation and data were statistically analyzed by correlation coefficient to study the statistical relationship. Anticipated performance index (API), air pollution tolerance index (APTI) calculations and other graphs has been formulated in Microsoft excel 2007 and Origin Pro 8 software.

RESULTS AND DISCUSSION

Total of fifteen tree species were assessed in selected areas of Rohtak city namely campus, residential and industrial area. In the present study leaves parameter like photosynthetic pigments, ascorbic acid, relative water content, potential of hydrogen ion concentration (pH) of leaf extracts and proline were used in evaluating their degree of tolerance to air pollution of Rohtak city.

Total chlorophyll content (tchl)

Chlorophyll content signifies photosynthetic activity as well as growth and development of plant biomass. Pollutants not only decrease the chlorophyll content but certain pollutants may increase the chlorophyll content so chlorophyll is regarded as the index of productivity of plant (Agbaire and Esiefarienrhe, 2009). In the present study the highest chlorophyll content was recorded in *F. benghalensis* (3.141 mg/gm fresh wt.).



Graph 1 Total chlorophyll content in tree species.

It might be due to higher chlorophyll content of tree species varies from species to species; age of leaf and also with the pollution level as well as with other biotic and abiotic conditions (Katiyar and Dubey, 2001). Therefore the campus area has low pollution level in comparison with industrial and residential sites. Second reason for higher chlorophyll content is wash out of dust particles from the leaves surface (which will increase the photosynthetic activity, low water content of soil as shown by (Shyam *et al*, 2006). The least chlorophyll content was reported at residential site in *A. lebbeck* (0.047mg/gm fresh wt.) followed by campus and industrial sites in *P. glabra* with the value (0.063mg/gm fresh wt.) and (0.108 mg/gm fresh wt.) respectively. . The trees having chlorophyll content in the range 4 to 16 mg/gm fresh wt. and 0.90 to 9.38 mg/gm fresh wt. are categorized as intermediately tolerant and sensitive tree species respectively. All the evaluated tree species in the present study were found to be sensitive to the air pollution. Second reason for the reduced value of chlorophyll may be the result of presence of gaseous sulphur dioxide in the air causing destruction of chlorophyll and that can be possible by the replacement of Mg^{2+} by two hydrogen atoms and degradation of chlorophyll molecule to phaeophytin.

Table 2 Evaluation of trees species on the basis of some biological and Socio-economic characters.

S.No.	Tree species	Biological and socio economic parameters			Laminar structure				
		TH	CS	TOP	Texture	Hardness	LS	EV	Total
1	*E. oblique*	++	+	+	+	++	++	+	10
2	*A. scholaris*	++	-	+	+	++	+	+	8
3	*B. variegata*	+	+	-	-	+	++	++	7
4	*Saraca asoca*	+	++	+	+	+	+	+	8
5	*F. virens*	++	+	-	-	-	++	-	5
6	*A. indica*	++	++	+	-	-	-	++	7
7	*F. religiosa*	++	++	+	+	+	+	+	9
8	*F. benjamina*	++	++	+	-	+	+	+	8
9	*A. lebbeck*	++	-	-	-	+	-	+	3
10	*P. glabra*	+	+	+	+	+	+	-	4
11	*F. benghalensis*	++	++	+	-	+	+	+	8
12	*P. guajava*	+	++	+	+	+	+	++	9
13	*Mangifera indica*	++	+	+	+	+	-	++	8
14	*S. cumini*	+	+	+	+	-	-	++	6
15	*Z.mauritiana*	+	++	-	-	+	-	++	6

TH: tree habitat, **CS:** canopy structure, **TOP:** Type of habitat, **LS:** leaf size, **EV:** economic value

Further decrease in chlorophyll content in the leaves can be due to alkaline condition created by dissolution of chemicals present in cell sap that is responsible for chlorophyll degradation. Degradation of photosynthetic pigment has been widely used as an indicator of air pollution (Ninave *et al*, 2001).Total chlorophyll of tree species is negatively correlated with air pollution tolerance index. Correlation coefficient values of chlorophyll of tree species studied at campus, residential and industrial sites with APTI are R^2= 0.157211, R^2= 0.004537 and R^2=0.010951 which are not significant.

Table 3 Correlation coefficient values of different biochemical parameters of tree species studied in campus area

	AA	pH	Tchl	RWC	APTI
AA	1				
pH	-0.31485	1			
TChl	0.46415	-0.45914	1		
RWC	-0.24737	0.04485	-0.41865	1	
APTI	-0.20113	0.03490	-0.39650	0.99875	1

AA-Ascorbic acid, **TChl**-Total Chlorophyll content**, RWC**-Relative water content, **APTI**-air pollution tolerance index

Table 4 Correlation coefficient values of different biochemical parameters of tree species studied in residential area

	AA	pH	Tchl	RWC	APTI
A A	1				
pH	0.61836	1			
TChl	0.28574	0.30203	1		
RWC	0.24621	0.04875	-0.08631	1	
APTI	0.29648	0.08766	-0.06735	0.99859	1

AA-Ascorbic acid, **TChl**-Total Chlorophyll content, **RWC**-Relative water content, **APTI**-air pollution tolerance index

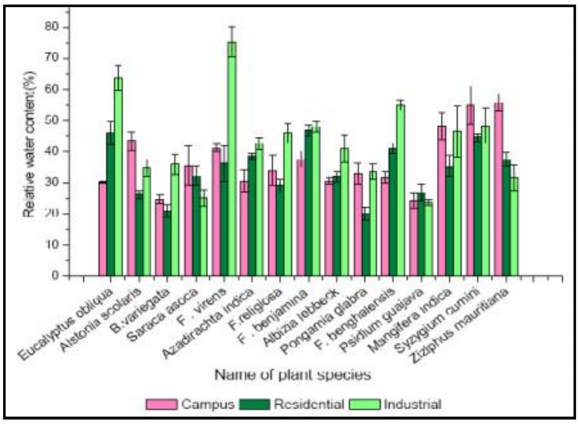
Table 5 Correlation coefficient values of different biochemical parameters of tree species studied at Industrial site

	AA	pH	Tchl	RWC	APTI
A A	1				
pH	0.50321	1			
TChl	0.51284	0.26863	1		
RWC	0.02718	0.12323	0.08594	1	
APTI	0.05739	0.14249	0.10464	0.99951	1

AA-Ascorbic acid, **TChl**-Total Chlorophyll content, **RWC**-Relative water content, **APTI**-air pollution tolerance index

Relative water content (rwc)

The maximum value of relative water content was recorded in *F. virens* (75.21%) at industrial site followed by *Ziziphus mauritiana* (55.84%) at campus and *F. benjamina* (46.91%) at residential site.

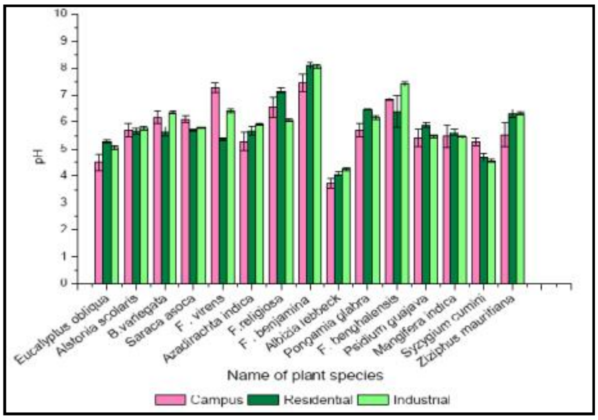


Graph 2 Relative water content in tree species

Higher the relative water content in a particular species greater is its drought tolerance capacity (Dedio 1975). Therefore the plants with high relative water content under polluted conditions may be tolerant to air pollutants. The minimum value was recorded in *Pongamia glabra* (23.73%) and *Psidium guajava* (24.32%), at both campus and residential sites followed by other tree species. Low relative water content of leaf means lower rate of availability of water in soil along with high rate of transpiration. Leaf water status is related with various physiological conditions such as transpiration, growth, respiration (Kramer and Boyer 1995). The tree species *P. guajava* and *P. glabra* was found to be sensitive species and can be used as bio-indicator. The tree species *F.virens* was found to be intermediately tolerant and rest of the species were sensitive species. The relative water content of tree species is positively correlated with air pollution tolerance index at all three sites. Correlation coefficient values of relative water content of tree species studied at campus, residential and industrial sites with APTI are R^2= 0.997506, R^2= 0.997191 and R^2=0.999035 which are the most significant and the determining factor on which tolerance depends in the present study.

Potential of hydrogen ion concentration of leaf extracts

The highest value (8.10), (8.07), (7.46) of potential of hydrogen ion concentration of leaf extract was analyzed in *F. benjamina* at all the three sites: residential, industrial and campus respectively.

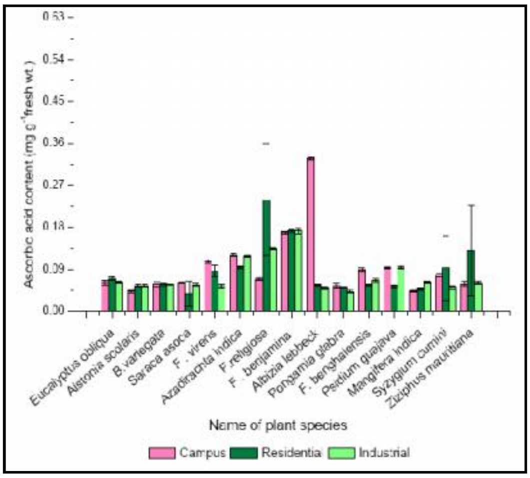


Graph 3 pH in tree species

The mean value of potential of hydrogen ion concentration ranges from 7-8. In *F. virens* and *F. benjamina* the values were found to be basic in nature which may be due to the presence of SOx and NOx in the ambient air cause changes in the potential of hydrogen ion concentration of low cell sap (Swami *et al,* 2004). The minimum value of potential of hydrogen ion concentration of leaf extract is in *Albizia lebbeck* (3.73), (4.24), (4.08) at residential, industrial and campus respectively. All the selected tree samples of all the three sites campus, residential and industrial exhibited mostly an acidic potential of hydrogen ion concentration of leaf extract, which may be due to dust accumulation hence the H^+ ion concentration of leaf extract is low i.e. the acidic condition might be caused by the less dissolution of dust particles in the cell sap (Scholz and Reck, 1977). Trees with the lower potential of hydrogen ion concentration are more susceptible while those with higher potential of hydrogen ion concentration are known to improve tolerance to air pollution (Singh and Verma, 2007). Potential of hydrogen ion concentration of leaf extract is positively correlated with air pollution tolerance index at all three sites. Correlation coefficient values of potential of hydrogen ion concentration of tree species studied at campus, residential and industrial sites with APTI are R^2= 0.001219, R^2= 0.007686 and R^2=0.020305 which are not significant.

Ascorbic acid (aa)

Maximum value of ascorbic acid is recorded in *Albizia lebbeck* (0.372) at campus site followed by *F. benjamina* (0.172) at both residential and industrial sites respectively. ascorbic acid. The increased ascorbic acid is because of

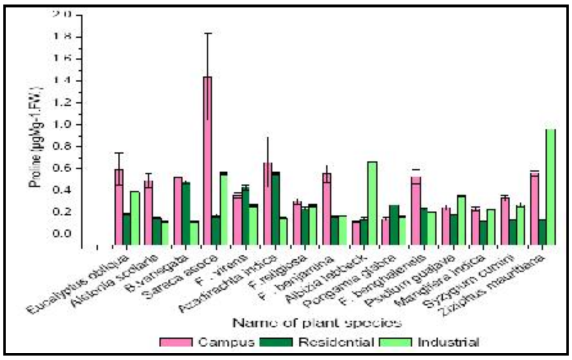


Graph 4 Ascorbic acid content in tree species.

defense level of respective plant (Cheng *et al,* 2007). It was reported, These indicated that those tree species having low chlorophyll content have high pollution load dependent increase in ascorbic acid content which may be due to the increased rate of production of reactive oxygen species (ROS) during photo oxidation process (Tripathi and Gautam, 2008). Ascorbic acid plays a significant role in cell wall synthesis, photosynthetic carbon fixation, defence and cell division (Seyyednejad *et al,* 2011). According to (Chaudhary and Rao 1977) and Varshney and Varshney 1982) are of the opinion that higher ascorbic acid content of the plant is a sign of its tolerance against sulphur dioxide pollution and pollutants which are normally affecting the roadside vegetation. The minimum value of ascorbic acid is recorded in *Saraca asoca* (0.037) at residential site followed by *Alstonia scholaris* (0.042) at campus site and *Pongamia glabra* (0.042) at industrial site respectively. Lower the ascorbic acid in tree species supports the pollutants particularly automobile exhaust (Conklin *et al,* 2001). Ascorbic acid is negatively correlated with air pollution tolerance index of campus site whereas positively correlated with air pollution tolerance index of residential and industrial sites only. According to table 3,4 and 5Correlation coefficient values of ascorbic acid of tree species studied at campus, residential and industrial sites with APTI are R^2= 0.040455, R^2= 0.0879 and R^2=0.003295 which are not significant and are not the determining factor on which tolerance depends in the present study.

Proline content

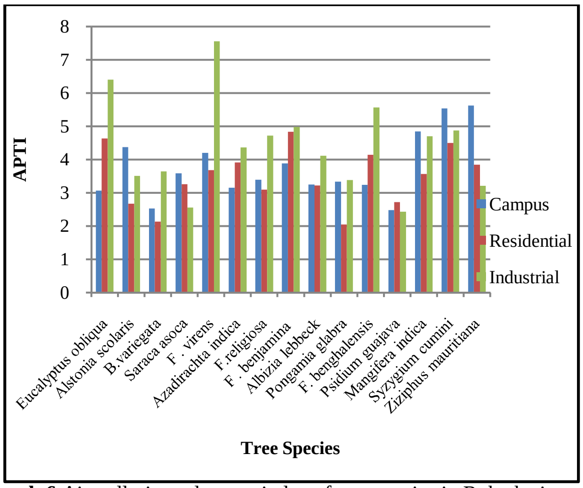
Graph-5 shown highest proline content is found in *Saraca asoca* (1.440 µmg g^{-1} fresh weight) of campus area followed by *Ziziphus mauritiana* (0.961 µmg g^{-1} fresh weight) of industrial area and *Azadirachta indica* (0.552 µmg g^{-1} fresh weight) of residential area respectively. The proline content depends on plant age, leaf age, leaf position or leaf part (Chiang and Dandekar, 1995). Highest proline content in campus area due to alkalinity stress conditions in the soil and at the industrial due to high pollutant concentration. The minimum proline content is found in *Albizia lebbeck* (0.106 µmg g^{-1} fresh weight), *Mangifera indica* (0.125 µmg g^{-1} fresh weight) and *Alestonia scholaris* (0.115 µmg g^{-1} fresh weight) respectively. A possible reason for low proline accumulation in the leaves could be enhanced protein synthesis or proline translocation to other parts of the plant, such as generative organs, or the roots which have to grow into deeper soil levels under drought conditions (Valentovic *et al,* 2006).



Graph 5 Proline in tree species.

Air pollution tolerance index (APTI)

For the calculation of air pollution tolerance index the five biochemical parameters plays an important role and their values provide indication of specific physiological response triggered by the pollution status and many other factors. It is evident from the table 3,4 and 5 that different trees respond differently to the air pollutants changes in five physiological and biochemical aspects of tree species results in the variation in air pollution tolerance index values. Thus, it can be concluded that each parameter plays a significant role in the determination of susceptibility level of trees which govern the competition of index.



Graph 6 Air pollution tolerance index of tree species in Rohtak city.

Anticipated performance index (API)

Presence of trees in the urban environment can thus improve air quality through enhancing the uptake of pollutant gases and particles (McPherson *et al,* 1994; Beckett *et al,* 1998; Freer-Smith *et al,* 1997). Dust interception capacity of plants depends on their surface geometry, phyllotaxy, leaf external characteristics (such as hairs, cuticle etc.) and height and canopy of trees (Nowak, 1994). APTI (air pollution tolerance index) and API (anticipated performance index) methodology can be applied anywhere in the world as they are based on biochemical parameters and universally relevant biological and socio-economic characters. Selected tree species were evaluated for biological and socio-economic with various biochemical factors. These parameters were subjected to a grading scale as shown in table 2 to determine the API (anticipated performance index) of tree species. A comparison of assessment parameters with respect to grading characters using a multiplication and summation of anticipated performance of tree species found those parameters to be quite similar with APTI (air pollution tolerance index). Tree species were evaluated for biological and socio-economic with various biochemical factors.

The present study categorized growing trees in Rohtak city into tolerant, moderately tolerant and sensitive tree species according to their air pollution tolerance index values (APTI). According to the present study results of air pollution tolerance index concluded that *F. virens* (7.557) and *E. obliqua* (6.405) at industrial site are highly tolerant trees species. *Ziziphus mauritiana* (5.621) at campus site and *F. benghalensis* (5.569) at industrial site are regarded as the intermediately tolerant tree species while *F. benjamina* (4.976) and *Syzygium cumini* (4.873) at industrial site are moderately tolerant tree species. Therefore, *F. virens*, *E. obliqua*, *Ziziphus mauritiana*, *F. benghalensis*, *F. benjamina* and *Syzygium cumini* tree species are very important in landscaping of Rohtak city whereas F. *virens*, *E. obliqua*, are the most tolerant tree species with high air pollution tolerance index values (APTI) which can be used as scavengers for identification and impact of combating in air pollution in Rohtak city industrial area. Hence the study is useful for better understanding and management of air quality as well as in selection of tree species with high air pollution tolerance index values (APTI) for pollution in industrial area as well as on roadside. These two above studied tolerant species can also be used as “sink” for air pollutants in industrial area of Rohtak city.

The present study also revealed that evaluation of anticipated performance index (API) of trees species is useful in the selection of suitable tree species for urban green belt development. Present study indicates *Eucalyptus obliqua is* the most tolerant plant to grow in industrial area and can be accepted to perform well for the development of “Green belt” in Rohtak city.

Trees species with low air pollution tolerance index values (APTI) serve as sensitive species and can be recommended as bio indicators. Trees species *B. variegata* (2.133) and *Pongamia glabra* (2.047) at residential site are having low air pollution tolerance index as a result they can be used as bio indicators for Rohtak city and it is known that bio indicator is a easy technique and inexpensive to control air pollution. Therefore, in net shell air pollution tolerance index values (APTI) determination is important in industrialized era for landscaping of the City. Results of the present study is helpful in landscaping of the City on the basis of sensitivity of tolerance to air pollution of tree species which is based on air pollution tolerance index values(APTI). Tolerant tree species (*E.obliqua*) plays an important role in reducing the overall pollution and sensitive species can be regarded as primitive indicators of pollution.

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