AIR POLLUTION TOLERANCE INDEX (APTI) OF FIVE SELECTED ROADSIDE PLANTS OF PRAYAGRAJ CITY

Article · January 2021

DOI: 10.1729/Journal.25549

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AIR POLLUTION TOLERANCE INDEX (APTI) OF FIVE SELECTED ROADSIDE PLANTS OF PRAYAGRAJ CITY

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ABSTRACT
Plant influenced greatly by pollutant concentration in air because of their continuous exposure. Air pollution modifies physiological activity of plant which results in stunted growth and decrease in productivity of plants. Thus the study was conducted to examine tree health in relation to air pollution with Air Pollution Tolerance Index (APTI) and API.
For the purpose five tree species (*Polyalthia longifolia*, *Azadirachta indica*, *Acacia nilotica*, *Ficus benghalensis* and *Mangifera indica*) from four different site (Rambagh, Civil Lines, National Highway 35 and National Highway 30) and 2 locations (two normal roadside plants and two petrol pomp plants) were selected and leaves are collected for analysis. An APTI score of ≤11, 12–16, and ≥17 classifies the tree species as sensitive, intermediate, and tolerant towards air pollution respectively. The anticipated performance index (API) of these plant species was also calculated by considering their APTI values together with other socioeconomic and biological parameters. API score of *Azadirachta indica* (93.75%) and *Acacia nilotica* (81.25%) were highest among selected plant species that make them best suited for Green Belt and Urban Forest. And lowest API was scored by *Polyalthia longifolia* (50%) which state it most effected plant from air pollutant and can be treated as indicator plant.

Keywords:
Air Pollution Tolerance Index, Anticipated Performance Index, Carotenoid, Total Chlorophyll Content, Relative Water Content, Ascorbic Acid.

I. INTRODUCTION

Plants play a vital role in biogeochemical cycling of nutrients to maintain the ecological balance in nature. They also provide enormous leaf area for impingement and act as a sink or living filters to minimize air pollution by absorption, adsorption, detoxification, accumulation and/or various metabolic activities without sustaining serious foliar damage or decline in growth (**Shannigrahi,2004; Escobedo,2008**). Planting of trees and shrubs for abatement of air pollution is an effective approach adopted worldwide **(Escobedo, 2008; Nugrahani, 2012)**.

Regional impact of air pollution on local plant species is one of the major ecological issues. Climate conditions, physico-chemical properties of air pollutants and their residence time in the atmosphere have impact on surrounding plants (**Wagh *et al.*, 2006**). The most obvious damage occurs in the leaves which include chlorosis, necrosis and epinasty (**Prasad and Choudhury, 1992**). Air pollutants enter plants leaves through stomatal pores during gas exchange of respiration and photosynthesis and passes into the intercellular spaces of mesophyll tissue causing various anatomical, morphological and physiological anomalies' **(Gupta and Ghouse, 1986).** The response of plants towards air was assessed by Air Pollution Tolerance Index (APTI). The usefulness of evaluating APTI for the determination of tolerance as well as sensitiveness of plant species were followed by several authors **(Agrawal and Tiwari, 1997; Dwivedi and Tripathi, 2007, Liu and Ding 2008; Dwivedi *et al.*, 2008).** It is an empirical relation which evaluates the tolerance level of plant species towards air pollution from leaf biochemical parameters such as Leaf extract pH, relative water content of the leaf, ascorbic acid and total chlorophyll. **(Singh and Rao, 1991)**

APTI provides a mean for discriminating pollution-tolerant plant species from the pollution sensitive ones. It helps generate valuable information for landscapers and greenbelt designers. While hyper-tolerant plant species are to be selected for large-scale plantation programmes as a component of social forestry in metropolitan areas, sensitive varieties may be used as bio-indicators of air pollution sensitive zones **(Seyyednejad, 2011).** Individual biochemical and physiological parameters often demonstrate conflicting results for some species (**Han, 1995**). Conversely, the APTI scores based on the combination of four salient parameters, such as ascorbic acid content (**Hoque *et al*, 2007**), chlorophyll content **(Flowers, 2007),** leaf extract pH **(Klump, 2000)** and relative water content (RWC) gave more reliable results than obtained with any of the aforesaid single parameters tested individually **(Singh,1991; Lakshmi, 2008; Choudhury, 2009).**

Prayagraj is among one of the Holy City hosting tourism for religious purpose. Thus beauty of surrounding matters and increasing air pollution level may effecting plant life drastically. Under such view this study is carried out to estimate plants health status with in reference to air pollution. This study determine the sensitivity / tolerance of common plants species towards air pollution growing on road side area in city and highway by calculating their APTI and API.

II. MATERIALS AND METHODS

2.1 Site description

Prayagraj is located at 25.45° N and 81.84° E in the southern part of Uttar Pradesh. It falls under subtropical climatic region with severe winter and harsh summer. Its elevation is over 90 m (295 ft.) above sea level. Its ancient name Prayagraj comes from meeting point SANGAM of three divine rivers of India- Ganga, Yamuna and the Mythical river of Saraswati. Thus the City falls under Holy City of India previously known as Allahabad. The City plays a central role in Hindu Scriptures. Prayagraj city has been taken from the purpose of finding air pollution index to demonstrate plant health in relation to air pollution.

2.2 Study area

In order to conduct the study, four sites have been selected. Prayagraj- Rambagh, Civil Lines, National Highway 35 and National Highway 30. In order to conduct the present study the detailed survey of the four sites was conducted and during the survey the distribution of plant species along both sides of City Roads and Highway Roads was recorded and five commonly growing species were identified and selected for the study. The plants selected for the study were *Polyalthia longifolia, Azadirachta indica, Acacia nilotica, Ficus benghalensis* and *Mangifera indica.* In order to maintain uniformity, plants of same age and spread growing at iso-ecological conditions were selected.

2.3 Experimental details

In order to conduct the present study the City roads and Highway Roads was divided into four location based on two normal roadside plants and two petrol pump plants.

2.4 Collection of samples

Sampling of plants selected at different study sites were based on a completely randomized design. Leaf samples were collected from the breast height of the plants and three samples were collected from each plant for record and analysis from different sites and placed in the marked polythene zip pack bags.

These samples were stored at 20°C and before conducting experiment washed with ordinary water and then with 0.1N HCL followed by washing with distilled water.

2.5 Sample analysis

The leaf samples were analysed for total chlorophyll, ascorbic acid, leaf extract pH and relative water content by using following standard procedures.

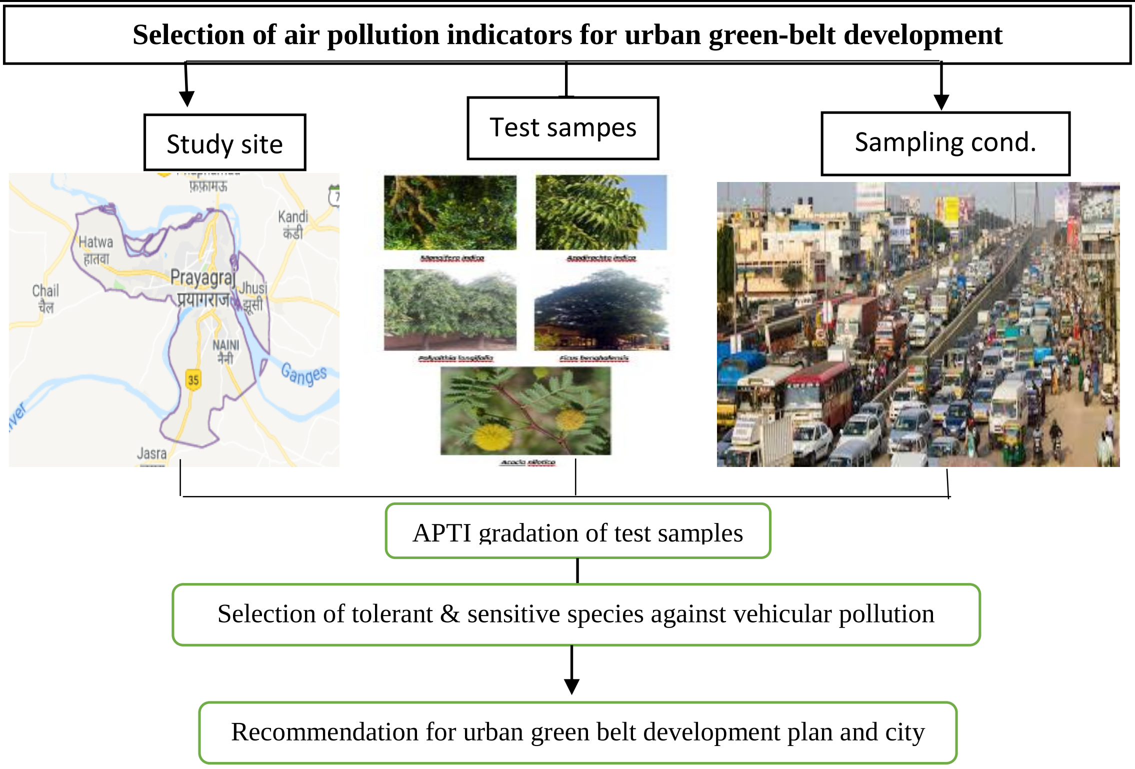
2.5.1 Leaf extract pH

Recently matured leaves (5g) were homogenized in 10 ml deionised water and supernatant obtained after centrifugation was collected for determination of pH by using pH meter **(Model- ESICO 1013)** with buffer solution of pH 4 and 9 **(Barrs and Weatherly, 1962).**

2.5.2 Relative water content

The relative water content was estimated by using the method of **Turner (1981).**

$RWC = \frac{(FW-DW)}{(TW-DW)}$ X 100, Where, RWC- Relative water content (%), FW- Fresh weight, TW- Turgid weight, DW- Dry weight of leaf samples.



2.5.3 Ascorbic acid content

Estimation of Ascorbic acid using 2, 6-dichlorophenol indole phenol titration Method 5ml of the working standard was taken with a pipette into a 100ml conical flask. 10ml of 4% oxalic acid was added and this was titrated against the dye. 1g of each of the sample was extracted in 4% oxalic acid and the volume made up to 100ml. This was then centrifuged at 10,000 rpm for 15 min. 5 ml of the supernatant was taken and 10ml of 4% oxalic acid added. This was titrated against the dye. The end point was the appearance of pink colour which persisted for a few minutes. The amount of the dye consumed is equivalent to the amount of the ascorbic acid.

2.5.4 Total Chlorophyll content

This was carried out according to the method described by **Arnon, (1949).** 3g of fresh leaves were blended and then extracted with 10ml of 80% acetone and left for 15 minutes for thorough extraction. The liquid portion was decanted into another test-tube and centrifuged at 2,500 rpm for 3 minutes. The supernatant was then collected and the absorbance taken at 645nm and 663nm using a spectrophotometer.

Calculations were done using the formula below:

$$\text{Chl.a} = \frac{\left(\frac{12}{7}*D_{663}\right)-\left(\frac{2}{69}*D_{645}\right)*V}{1000*W}$$

Based on these characters, different grades (+ or -) are allotted to plants. Different plants are scored according to their grades as per the procedure outlined by **Mondal *et al*., 2011.**

$$\text{Chl.b} = \frac{\left(\frac{22}{9}*D_{645}\right)-\left(\frac{4}{68}*D_{663}\right)*V}{1000*W}$$

Total Chlorophyll Content (mg/g) = $20.2(A_{645})+8.02(A_{663})\frac{V}{1000*W}$

Or

Total chlorophyll = Chlorophyll a + b mg/g

Where, D = Absorbance of the extract at the wavelength in nm, V = Total volume of the chlorophyll solution (ml), W = Weight of the tissue extracted (g).

2.5.5 Air pollution tolerance index (APTI)

By using the above parameters the air pollution tolerance index was computed by the method suggested by **Singh and Rao (1983)** using the equation:

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

Where, A = Ascorbic acid (mg/g) of leaf sample, T = Total chlorophyll (mg/g) of leaf sample

P = Leaf extract pH of leaf sample, R = Relative water content (%) of leaf sample.

2.5.6 Anticipated Performance Index (API)

By combining the resultant APTI values with some relevant biological and socioeconomic characters (plant height, canopy structure, plant size texture, hardness and economic value) the API was calculated for different plant species.

Anticipated Performance Index is particularly in useful in selection of those species for plantation which can perform a dual function of improving the air quality and providing aesthetic and recreational value. API can be calculated by the formula-

$$API = \frac{no.of\ '+'\ obtained}{Total\ no.\ of\ '+'\ obtained} * 10$$

Table 2.1: Gradation of plant species on the basis of Air Pollution Tolerance Index (APTI) and other biological and socio-economic characters (Mondal *et al.*, 2011)

Grading	Character	Pattern of assessment	Grade allotted
Tolerance	Air Pollution Tolerance Index (APTI)	9.0-12.0 12.1-15.0 15.1-18.0 18.1-20.0 20.1-24.0 24.1-32.0 32 and above	+ ++ +++ ++++ +++++ ++++++ +++++++
Biological character	Plant habit	Small , Medium, Large	-, +, +
	Canopy structure	Sparse/Irregular/globular Spreading crown/open/semi dense Spreading dense	- + ++
	Type of plant	Deciduous, Evergreen	-, +
Leminar structure	Size Texture Hardness	Small, Medium, Large Smooth , Coriaceous Delineate, Hard	-, +, ++ -,+ -, +
Socio-economic	Economic value	less than three uses Three or four uses Five or more uses	- + ++

Table 2.2: Anticipated Performance Index (API) of plant species.

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

III. RESULTS AND DISCUSSION

An overview of the result obtained from this study reveals that different plants respond differently to air pollutants. The variation of the APTI can be attributed to the variation in any of the physiological factors which governs the computation of the index. The physiological and biological characteristics that were considered in the study were- pH, Relative water content (RWC), Ascorbic acid and Total chlorophyll content.

3.1 Physico-chemical parameters-

3.1.1 pH

pH is biochemical parameter that act as an indicator for sensitivity to air pollution. The plants samples collected from selected site exhibited a pH towards acidic site which may be due to the presence of SO_2 and NO_2 in the ambient air causing a change in pH of the leaf sap towards acidic site. In the present study the pH varies from 8.9 to 5.6. Basically low pH has caused reduction in photosynthesis rate by disturbing the gaseous exchange through stomata **(Escobedo *et al*. 2008; Joshi and Bora 2011),** but sometimes plant is healthy and it showed low leaf surface pH due to the age of leaf **(J.J Orteli 1977**), diurnal variations (maximum at the end of the night and decreased during the late morning (**Olivier Husson et al., 2018)**

3.1.2 Relative water content (%)

RWC can be used as indicator of physiologically active plant that may withstand certain degree of stress. In RWC significantly varied from 89.5 to 69.39. The high RWC in plants regulates the physiological functions of plants under stress condition, particularly, when plants get exposed to high levels of airborne pollutants **(Tsega and Prasad, 2014)**. Higher the RWC, better the tolerance capacity of the plants against air pollution **(Paulsamy *et al.* 2000).** RWC is a crucial factor to regulate the physiological balance during high transpiration rate and it accelerates during drought condition **(Swami *et al* 2004; Joshi and Swami 2007).** It has been extensively reported that as the concentration of air borne pollutant increases, cell permeability of plant leaves also increase, which results in loss of water and nutrient, and ultimately leads to early senescence **(Tsega and Prasad, 2014).**

3.1.3 Ascorbic Acid (mg/g)

The concentration of ascorbic acid varied from species to species. Ascorbic acid is a natural antioxidant that influences the resistance of plants against adverse environmental conditions and helps in pollution tolerance **(Subramani and Devaanandan, 2015)**. In the present study the Ascorbic Acid significantly varied from 20.10 to 1.16. The increase in leaf ascorbic acid may also be due to improvement in the defence mechanism of the plants which has been reported to be different for each plant species by **(Chen *et al.*, 2007).** Trees under stress improve their ascorbic acid content to improve their capacity to fight against adverse conditions. The results are in line with the findings of **Yannawar and Bhosle (2013)** who have also reported higher ascorbic acid content in the leaves of the plants growing near roadside due to higher pollution stress**.**

3.1.4 Total Chlorophyll content (mg/g)

The leaf Chlorophyll content of selected plant species varied significantly from 6.70 to 0.48. It is known that chlorophyll content of plant varies from species to species; age of leaf and also with the pollution level as well as with other biotic and abiotic condition **(Katiyar and Dubey, 2001)**. Since chlorophylls are the chief photosynthetic pigments, their content signifies growth and development of biomass and overall health status of plants. Decrease in chlorophyll content has been suggested as an indicator of SO_2 pollution. High amount of gaseous SO_2 causes destruction of chlorophyll and that might be due to the replacement of Mg++ by two hydrogen atoms and degradation of chlorophyll molecules to phaeophytin. A considerable loss of total chlorophyll in the plants exposed to pollutants supports the argument that the chloroplast is the primary site of attack by air pollutants such as SOx and NOx **(Tripathi *et al.*, 2007**). Sometimes chlorophyll content is low due to difference between in young and adult leaves of same plant species, the chlorophyll content was high in adult leaves in comparison to young leaves **(Siwach and Gill, James *et al.*, 1999).** TC content is also affected by dust captured by the plant leaves, probably due to blockage of stomatal opening /closing which causes decreases in the rate of photosynthesis by disturbing the gaseous exchange **(Leghari and Zaidi 2013).**

Table 3.1: pH of selected plant species at different sites.

Plants species/ Sites	**Site-1 Rambagh**				**Site-2 Civil lines**				**Site-3 NH-35**				**Site-4 NH-30**			
	Normal roadside		**Petrol pump site**		**Normal roadside**		**Petrol pump site**		**Normal roadside**		**Petrol pump site**		**Normal roadside**		**Petrol pump site**	
Polyalthia longifolia	6.30	5.40	5.90	5.70	6.00	6.10	6.70	6.30	6.90	6.80	7.00	6.90	7.10	6.80	7.20	6.70
Azadirachta indica	5.40	5.30	6.10	6.50	6.30	6.70	6.00	6.20	6.90	6.70	6.20	6.80	6.30	7.00	6.90	6.90
Acacia nilotica	5.90	5.60	5.90	5.80	6.50	5.80	5.60	6.40	6.10	6.80	6.50	6.30	6.40	6.80	6.10	6.10
Ficus benghalensis	7.80	7.30	7.60	7.90	7.80	7.00	7.10	8.40	8.20	8.50	8.60	8.90	8.90	8.70	8.60	8.50
Mangifera indica	5.70	5.60	5.60	5.30	6.00	5.90	5.70	6.90	7.10	6.20	6.00	6.10	6.20	6.90	7.20	7.00

Table 3.2: Relative water content (%) of selected plant species at different sites.

Plants species/ Sites	**Site-1 Rambagh**				**Site-2 Civil lines**				**Site-3 NH-35**				**Site-4 NH-30**			
	Normal roadside		**Petrol pump site**		**Normal roadside**		**Petrol pump site**		**Normal roadside**		**Petrol pump site**		**Normal roadside**		**Petrol pump site**	
Polyalthia longifolia	80.53	81.3	84.2	80.3	79.38	72.4	75.4	72.3	71.33	67.6	76.4	73.2	77.10	87.2	81.6	83.9
Azadirachta indica	77.90	73.4	79.0	76.0	74.32	75.2	82.3	74.8	65.39	79.3	76.0	81.1	87.27	71.9	73.5	78.1
Acacia nilotica	74.70	78.0	81.0	83.4	78.60	79.0	77.9	78.8	79.01	78.4	72.4	79.5	80.46	81.0	79.4	79.8
Ficus benghalensis	77.75	79.1	75.8	79.8	77.50	78.9	85.7	81.5	75.88	79.8	77.4	76.4	78.19	71.8	76.5	73.4
Mangifera indica	85.08	82.4	86.0	81.0	83.66	83.2	80.0	77.8	79.32	82.3	84.3	89.5	78.59	78.2	79.9	70.1

Table 3.3: Ascorbic acid (mg/g) of selected plant species at different sites.

Plants species/ Sites	**Site-1 Rambagh**				**Site-2 Civil lines**				**Site-3 NH-35**				**Site-4 NH-30**			
	Normal roadside		**Petrol pump site**		**Normal roadside**		**Petrol pump site**		**Normal roadside**		**Petrol pump site**		**Normal roadside**		**Petrol pump site**	
Polyalthia longifolia	5.09	5.19	7.27	6.71	8.95	6.11	5.22	5.81	3.97	4.81	5.64	5.28	4.22	3.9	6.61	6.42
Azadirachta indica	15.36	12.5	12.3	13.8	18.2	17.0	15.9	17.46	20.1	17.60	13.9	14.8	19.20	18.4	17.8	15.6
Acacia nilotica	12.62	10.4	7.36	8.62	11.0	11.6	9.50	7.10	17.8	17.25	15.0	14.9	17.60	17.8	14.6	12.8
Ficus benghalensis	8.53	7.46	8.20	7.08	5.57	6.02	3.26	4.70	6.70	6.40	5.90	2.50	12.80	13.3	7.10	4.20
Mangifera indica	3.85	3.15	3.77	4.00	6.45	5.36	5.50	3.85	1.16	1.16	8.33	8.12	7.27	7.76	4.32	3.68

Table 3.4: Total chlorophyll content (mg/g) of selected plant species at different sites.

Plants species/ Sites	**Site-1 Rambagh**				**Site-2 Civil lines**				**Site-3 NH-35**				**Site-4 NH-30**			
	Normal roadside		**Petrol pump site**		**Normal roadside**		**Petrol pump site**		**Normal roadside**		**Petrol pump site**		**Normal roadside**		**Petrol pump site**	
Polyalthia longifolia	1.96	1.87	1.82	1.98	2.33	2.36	2.20	2.12	1.90	1.89	1.76	1.62	1.88	1.78	1.68	1.90
Azadirachta indica	3.68	3.10	1.80	1.97	3.10	2.98	2.82	3.81	5.24	6.66	4.70	5.44	6.54	6.29	5.73	5.64
Acacia nilotica	5.72	5.44	5.48	5.21	5.60	6.04	5.24	5.09	6.27	5.25	5.50	5.55	3.03	4.20	2.92	2.54
Ficus benghalensis	4.20	4.16	4.12	4.00	3.32	3.70	2.60	2.70	3.18	4.08	2.98	2.62	6.09	6.70	6.30	6.36
Mangifera indica	2.50	1.10	0.90	0.48	1.85	1.08	2.41	1.18	1.17	2.52	2.00	2.50	3.89	3.20	2.29	2.82

3.2 Air Pollution Tolerance Index (APTI)

APTI plays a significant role to determine resistivity and susceptibility of plant species against pollution level. Plant which have higher index value are tolerant to air pollution, while plants with low index value showed less tolerance and can be used to indicate levels of air pollution. In this present study the APTI value varies from 32.49 to 9.25. *Azadirachta indica* was found most tolerant plant species followed by *Acacia nilotica* and the most effected plant species is *Mangifera indica* and *Polyalthia indica*. *Azadirachta indica* showed low pH but has high APTI is due to the tree having a high APTI score showed a low acidic pH in their leaves with a high chlorophyll content and maximum RWC (**Nayak *et al* ., 2018**).

Table 3.5: APTI and Related Gradation of selected plant species at different sites.

Plants species/ Sites	Site-1 Rambagh		Site-2 Civil lines		Site-3 NH-35		Site-4 NH-30	
	Normal roadside	Petrol pump site	Normal roadside	Petrol pump site	Normal roadside	Petrol pump site	Normal roadside	Petrol pump site
Polyalthia longifolia	21.19 Intermediate	14.49 Sensitive	13.88 Sensitive	12.34 Sensitive	12.2 Sensitive	10.78 Sensitive	13.97 Sensitive	11.39 Sensitive
Azadirachta indica	17.71 Intermediate	17.84 Intermediate	24.28 Intermediate	23.63 Intermediate	30.69 Tolerant	24.48 Intermediate	32.49 Tolerant	28.6 Intermediate
Acacia nilotica	21.33 Intermediate	16.47 Sensitive	21.21 Intermediate	17.32 Intermediate	29.26 Intermediate	25.42 Intermediate	26.16 Intermediate	20.11 Intermediate
Ficus benghalensis	17.06 Intermediate	16.8 Sensitive	14.13 Intermediate	12.54 Sensitive	15.62 Sensitive	12.54 Sensitive	27.33 Intermediate	15.96 Sensitive
Mangifera indica	11.00 Sensitive	10.73 Sensitive	12.72 Sensitive	11.67 Sensitive	15.47 Sensitive	9.25 Sensitive	15.42 Sensitive	11.86 Sensitive

Table 3.6: Biological and Socio- ecological Characters of Plant species selected for evaluation of Anticipated Performance Index (API)

Plants	Biological and socio- economic characters							
	TH	CS	TT	LEMINAR			ECONOMIC IMPORTANCE	TOTAL NO. OF '+'
				Size	Texture	Hardiness		
Polyalthia longifolia	++	+	+	+	+	-	+	7
Azadirachta indica	++	++	+	-	+	+	++	9
Acacia nilotica	++	+	-	-	+	+	+	7
Ficus benghalensis	++	++	+	+	-	+	+	8
Mangifera indica	++	++	+	+	+	+	++	10

3.3 Anticipated Performance Index (API)

API is used as an indicator to assess the capability of predominant species for the abatement of the atmospheric pollutants and in green belt development. The anticipated performance index calculated by evaluation and grading of tree species based on their APTI and some biological and socioeconomic characters showed a variation from not recommended category to the category good.

In the present study API % score varies from 50% to 93.75%. Among the selected plant species, *Azadirachta indica* with highest API grade (93.75%) was in Best category followed by *Acacia nilotica* with API grade (81.25%) was in excellent category and minimum was observed in *Polyalthia longifolia* with API grade (50%) was in poor category. The highest value of API of *Azadirachta indica* may be due to its high APTI. Further, the better laminar characteristics like leaf size, texture, canopy structure along with the high economic value might have enhanced its API value towards the very good. Whereas, the small leaf size, smooth surface of leaf and comparatively less economic importance have perhaps decreased the API value. These findings are in accordance with **Prajapati and Tripathi (2008)** who have also reported more value of API for the species with higher APTI having better plant and leaf characteristics.

IV. CONCLUSION

This study concludes that Physico-chemical trait varied significantly from one location to other for selected genus. Petrol pump location of Rambagh area found to be most affected and National Highway 30 showed least effected.

Among all sites, at Petrol pump location of Rambagh site showed minimum APTI value and National Highway 30 showed maximum APTI value. Based on APTI value *Azadirachta indica* was found tolerant while *Acacia nilotica* and *Ficus benghalensis* was found intermediate and *Mangifera indica* and *Polyalthia longifolia*, comes under sensitive category.As per Anticipated Performance Index all plant species *Azadirachta indica* and *Acacia nilotica* scored highest API value at both location and best suited for Green Belt and Urban Forest at the same time *Polyalthia longifolia* is least tolerant from selected plant species and categorised under poor category.

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