Prepublished copy

Nature Environment & Pollution Technology

This is a peer-reviewed prepublished version of the paper

Type of the Paper (Original Research)

Comparative Assessment of Pollution Indices of Selected Tree Species in Urban, Industrial, Institutional and Agricultural Setups at Sonipat, Haryana, India

Rimpi Antil[1], Nisha Kumari[1] and Dharmendra Singh[2†]

[1] Center of Excellence for Energy and Environmental Studies (CEEES), Deenbandhu Chhotu Ram University of Science and Technology (DCRUST) Murthal, Sonipat-131039 (Haryana), India; rimpi.antil55@gmail.com; nishadahiya.energy@dcrustm.org

[2] Haryana Space Applications Centre (HARSAC), Citizen Resource Information Department (CRID), CCS HAU Campus, Hisar-125004, Haryana, India; dsbaghel0184@gmail.com

† Corresponding author: Dr. Dharmendra Singh; dsbaghel0184@gmail.com
Address- Haryana Space Applications Centre (HARSAC), Citizen Resource Information Department (CRID), CCS HAU Campus, Hisar-125004, Haryana, India

ORCID IDs of Authors

Rimpi Antil- http://orcid.org/0000-0003-4905-263X

Nisha kumari- http://orcid.org/0000-0002-4703-4449

Dharmendra Singh- http://orcid.org/0000-0001-8528-8637

Key Words	APTI; API; Environmental setups; Pollution indices; Tree species; Tolerant plants
DOI	https://doi.org/10.46488/NEPT.2025.v24i04.B4303 (DOI will be active only after the final publication of the paper)
Citation of the Paper	Antil, R., Kumari, N. and Singh, D., 2025. Comparative assessment of pollution indices of selected tree species in urban, industrial, institutional and agricultural setups at Sonipat, Haryana, India. *Nature Environment and Pollution Technology*, 24(4), p. B4303. https://doi.org/10.46488/NEPT.2025.v24i04.B4303

Abstract: Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API) of *Azadirachta indica, Ficus benghalensis* and *Ficus religiosa* were compared for the tolerance towards the air pollution in different environmental setups. The study was conducted at six different locations with different environmental setups including Urban, Industrial, Institutional and Agricultural. The parameters used for APTI were pH, relative water content, total chlorophyll content and ascorbic acid content in the leaves while API was calculated using APTI and socio-economic characteristics of the targeted species. Selected three species with nine replicates of each species from each setup (i.e. 3×9×6 which means a total of 162 samples) were analysed for APTI during winter season when there is lower mixing height that prevents the dispersion of pollutants and makes the environment highly polluted and trees shows high tolerance in polluted environment. The APTI values of all the targeted species were higher in industrial as compared to the other environmental setups i.e., 20.42 ± 1.65 for *A. indica* 14.75 ± 0.53 for *F. benghalensis* and 13.39 ± 1.11 for *F. religiosa*. Two sample t-Test shows significant difference in APTI of industrial setup and other setups (p=0.0000). It was found that the *A. indica* is tolerant species and *F. benghalensis* and *F. religiosa* are intermediate tolerant species on the basis of APTI. F. *benghalensis* and *F. religiosa* falls under excellent and *A. indica* falls under very good species category on the basis of API. Based on these two indices the best tree species were identified for plantation and abatement of air pollution in industrial areas.

1. INTRODUCTION

Rapid industrialization and unplanned urbanization have greatly increased air pollution, necessitating the use of natural alternatives for sustainable urban environmental management (Alotaibi et al. 2020). Plants plays an important role in improving air quality as they act as sink for air pollutants. They act as living filters and remove particulate matter (PM) from the air mass (Roy et al. 2024). Without causing foliar damage, plants remove air contaminants through adsorption, absorption, detoxification, metabolization, or accumulation of heavy metals (Li et al. 2023; Sumathi et al., 2023). However, plants not only purify the air by bio-filtering the contaminants through adsorption, absorption and impingement (Escobedo et al. 2008) but also have positive impact on water quality and soil of that area besides adding aesthetic value to it (Pradhan et al. 2016). A few trees exhibit tolerant behaviour towards a particular air pollutant while few are sensitive to it. The tolerant species appropriate for plantation and sensitive species are used as bio-monitors as well as bioindicators for giving qualitative and quantitative information of the surroundings (Choudhury et al. 2009). Certain species are good indicators of atmospheric pollution, whereas others are good accumulators based on physiological responses (Simon et al. 2021). Plants have been indirectly affected by soil acidification while the particulate and gaseous pollutants have direct effect on many physiological, morphological and biological characteristics of trees (Steubing et al. 1989; Sharma et al. 2013).

APTI was developed by Singh and Rao in 1983, using the aggregation of four biochemical parameters namely, leaf chlorophyll content, leaf extract pH, Relative Water Content (RWC) and Ascorbic Acid (AA) content. The chlorophyll is the food producing factory and an important indicator of the plant health (Ebrahimi et al.2023). The leaf pH directs the photosynthetic efficiency of trees and relative water content facilitate transpiration and provides cooling sensation to trees (Gonzalez et al. 2001). The AA is primary defense factor and it works against many oxidative damages to trees during water stress conditions and also helps in cell division and synthesis of cell wall. Plants experience physiological changes before showing visible changes to leaves (Dohmen et al. 1990). These include changes in stomatal properties, modifications to metabolic products, effects on gas exchange and photosynthetic activity, and effects on plant growth (Roy et al. 2024).

Analysis of some biophysical parameters of tree species helps in determining the tolerance level of trees. Many different researchers highly praise the APTI due to its combination of multiple parameters providing a more trustworthy outcome than any research that relies just on one parameter (Sahu et al. 2020; Bharti et al. 2018; Balasubramanian et al. 2018).

People frequently take advantage of plants for a variety of reasons. Trees, shrubs, and hedges are examples of urban greenery systems that improve air quality at the city level by acting as barriers and sponges for airborne pollutants (Yu et al. 2022). Thus, choosing plants only based on how well they tolerate air pollution and then recommending them for planting could result in a failure to manage these plants and ensure their survival., An improved calculation, known as the Anticipated Performance Index (API), was developed by Moore et al. (1986), by combining the biochemical parameters (similar to the APTI) with pertinent biological and socioeconomic characteristics of a species (Raza et al. 1988; Mondal et al. 2011). As a result, this index served as a perfect and more trustworthy resource for suggesting plant species for modern landscaping projects.

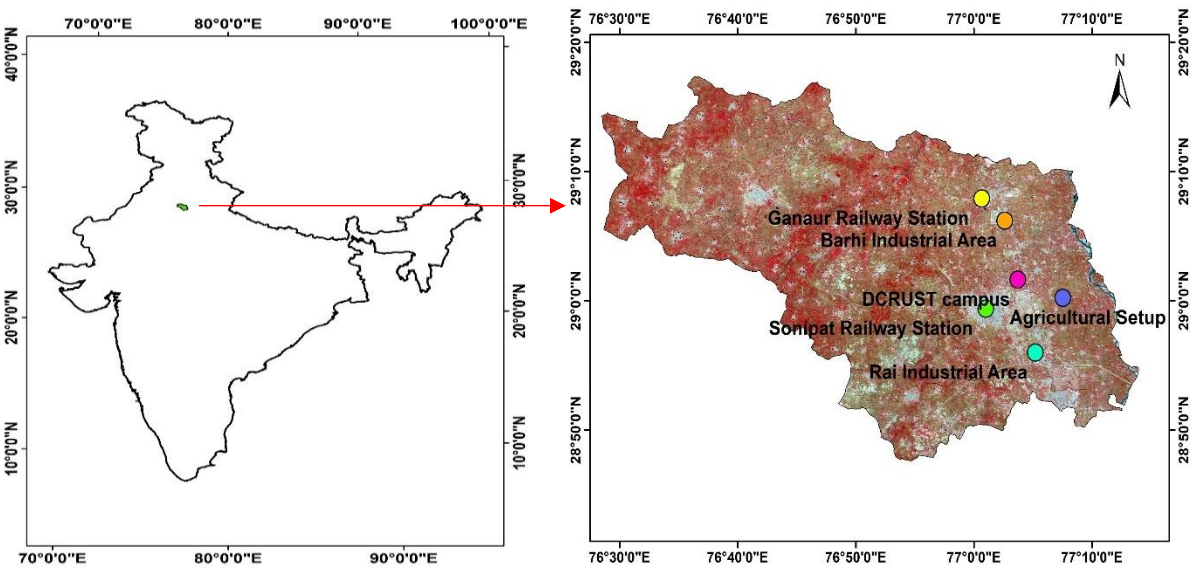
Balasubramanian et al. (2018), perform a study in Tamil Nadu, India based on the assessment of APTI of trees in different zones i.e., Residential, Industrial, commercial, Heavy traffic zone and control zone and identified the tolerant species for combating air pollution in the different zones. According to a study done by Roy et al. (2020) at Jharkhand, *A. Indica* and *F. religiosa* were identified as tolerant and *F. benghalensis* was identified as intermediately tolerant in Industrial environment, Commercial and Control setup. *F. benghalensis*, *F. religiosa* and *A. indica* were identified as tolerant species towards air pollution on the basis of APTI at control and polluted site in Lucknow (Bharti et al. 2018). Another study by Sahu et al. 2020 at Sambalpur in polluted and control setups reported *F. religiosa*, *F. benghalensis* and *A. indica* as excellent species on the basis of API. Though there are some studies across various parts of the country, the similar assessment is not available for the Sonipat area. However, the same is an industrial area along with a variety of environmental setup and near to the capital Delhi which is the worlds most polluted region. Thus, there is a need to work in different environments of Sonipat for assessment of APTI because a few studies have been done in this field. The current study was conducted to determine the tolerance of selected tree species (*A. indica; F. benghalensis and F. religiosa*) towards air pollution in variable environmental setups at district Sonipat by using their APTI and API. However, various studies on the basis of APTI were conducted in different areas with multiple species but no literature is available for comparison of tree species grown in Agriculture setup along with Industrial, Urban and Institutional setup. Plants may alter their biochemical properties to adjust to the ever-changing environment; these changes will mostly impact the levels of chlorophyll, ascorbic acid, leaf pH, and relative water content. This study focusses on analysis of changes in the above-mentioned parameters in different environmental setups and finding the best species for plantation. The identification of tolerant tree species is helpful for the purpose of greenbelt development in industrial area. The objective of the study is to compare the APTI and API of three selected tree species in urban, Industrial, Institutional and Agriculture setup. To study the impact of air pollution on biochemical parameters of selected tree species. To compare the API values of selected tree species for air pollution reduction.

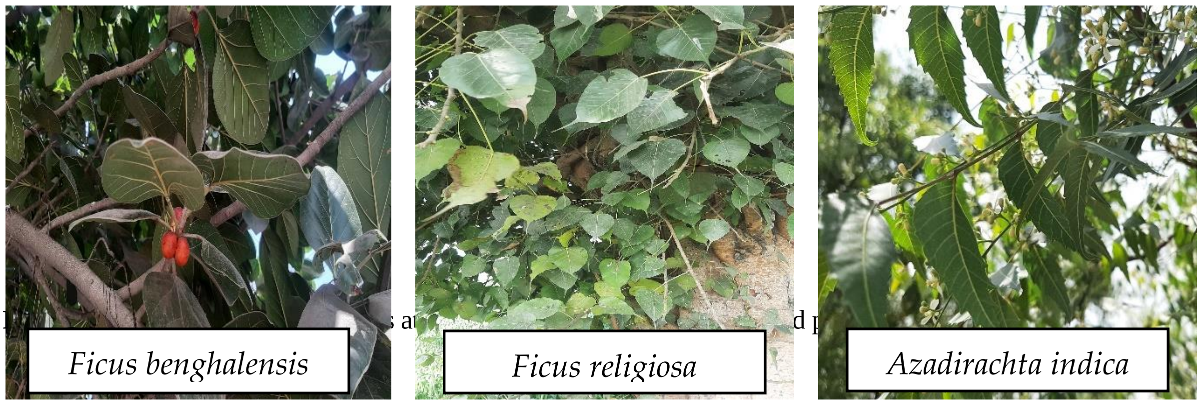
2. Materials and Methods

2.1 STUDY AREA

The APTI of *Ficus religiosa*, *Ficus benghalensis* and *Azadirachta indica* was calculated over different environmental setups including Urban, Industrial, Institutional and Agricultural in Sonipat district of Haryana, India. **Figure 1** shows location of the sampling sites and images of tree species studied. The district was bounded by 28° 48’15” to 29° 17’10” North latitude and 76° 28’40” to 77° 12’45” East longitude. The district comes under the National

Capital Region and the climate of the region is semi-arid with hot and dry summer. The samples were collected in the month of January-February when there is lower mixing height that prevents the dispersion of pollutants and makes the environment highly polluted (Murthy et al. 2020). Based on LULC Sonipat has around 87% Agricultural land (185000 ha), 5% Built-up (10716.12 ha), 3.47% Forest (7359 ha), 3.56% Waste land (7556 ha), 0.64% Water bodies (1357.87 ha), 0.10% Others (211 ha) of the total 2,12,200 ha area (TCP, Haryana, Interim Report II, 2021)





2.2 METHODOLOGY

2.2.1 Sampling of trees

A field survey was conducted randomly and leaf samples were collected along with the locations of trees. *Ficus religiosa*, *Ficus benghalensis* and *Azadirachta indica* were identified ocularly as the tolerant trees on the basis of previous studies and considered for further analysis. All the three tree species are called "Triveni" in India and are sacred trees therefore locally available at all the sampling sites and people avoid commercial cutting of these trees. *Azadirachta indica* and *Ficus benghalensis* are evergreen species and *Ficus religiosa* is semi-evergreen species. Additionally, their leaf size and canopy structure increase their ability to reduce pollution (Yadav et al. 2020). All the species are considered tolerant species on the basis of literature review in different areas with different seasons and environments (Enitan et al. 2022; Roy et al. 2020). From each setup, nine individual trees of each species were selected. Fully matured leaves were randomly collected at 6:00 to 8:00 am in the morning to avoid variability due to environmental changes, to stabilize metabolic activity, to ensure high turgor pressure and to reduce the diurnal fluctuations as the fresh weight of leaves is important to calculate and these factors makes measurements more reliable (Weatherley (1951)). The leaves were packed in sealed polythene bags and taken to lab without delay. The fresh weight of leaves was taken and the samples were preserved at 4°C. A composite leaf sample of each tree was prepared and further analysed.

2.2.2 Biochemical Analysis

2.2.2.1. Relative Water Content (RWC)

Fresh weight (FW) of the leaves was obtained by weighing the fresh leaves. The leaves were immersed in water overnight, blotted dry and then the turgid weight (TW) of leaves was measured. The leaves were dried overnight in oven at 70 °C and dry weight (DW) was obtained. Leaf RWC was calculated using the Eq 1 given by Singh et al. 1983.

$$RWC = \frac{(Fresh\ Weight - Dry\ Weight)}{(Turgid\ Weight - Dry\ Weight)} \times 100 \qquad \ldots(1)$$

2.2.2.2 Leaf Extract pH (pH)

Fresh leaf samples of 5 gm were crushed and homogenized in 50 ml of deionized water and the mixture was centrifuged. The supernatant was collected and the pH was measured using pH meter (HQ 40d) (Rai et al. 2014).

2.2.2.3 Total Chlorophyll content (TCh)

One gram of fresh leaves was grinded and extracted with 10 mL of 80% acetone and the extract was left for 15 min and centrifuged at 2500 rpm for 3 min. The supernatant was collected and the absorbance was taken at 645 and 663 nm using a spectrophotometer (Shimadzu uv-2600i). Calculations was made by using the Eq 2 (Jain et al. 2019).

$$Total\ Chlorophyll\ = 20.2A_{645} + 8.02A_{663} \times \frac{V}{1000W}\ mgg^{-1} \qquad \ldots(2)$$

2.2.2.4 Ascorbic Acid (AA)

The ascorbic acid content was determined using the modified calorimetric 2,6- dichlorophenol indophenol method given by Roy et al. 2020. 2.5 g sample is extracted in 4% oxalic acid and made it to known volume (25 mL) and centrifuged at 2500 rpm for 5 min. 5 mL of supernatant is pipette out and 10 mL oxalic acid is added and titrated against the dye. The calculations were done using Eq 3.

$$Ascorbic\ acid = \frac{0.5mg \times V_2 \times 25mL}{v_1\ ml \times 5\ ml \times wt\ of\ the\ sample} mg/g \quad \ldots(3)$$

Where,

V1=volume of dye titrated against the working standard

V2= volume of dye titrated against the sample

2.2.2.5 APTI and API Calculations

Based on the calculations of above parameters APTI was calculated by using the formula proposed by singh et al. 1983.

$$APTI = \frac{A \times (T+P)+R}{10} \quad \ldots(4)$$

Where, A- ascorbic acid content (mg/g); T- Total chlorophyll content (mg/g); P- leaf extract pH, R- Relative water content (%). Further the APTI values of trees were classified according to singh et al. 1991 **Table 1**.

Table 1: Standard of gradation level for APTI and response (Singh et al.1991; Bharti et al.2018)

Sr. No.	**APTI**	**Category**
1	≤ 11	Sensitive
2	12-16	Intermediate Tolerant
3	≥ 17	Tolerant

API of plant species was calculated by the combination of APTI and some socio-economic and biological characters. The method was proposed by moore et al.1986. **Table 2** shows the Gradation of plants on the basis of APTI and Biological and Socio- Economic characters Based on these characteristics different grades (+/-) are allotted to plant species and API score was calculated. The criteria used for API calculation is given in **Table 3** (Mondal et al. 2011).

$$API = \frac{No.of\ '+'obtained}{Total\ No.of\ '+'} \times 100 \quad \ldots(5)$$

Table 2: Gradation of plants on the basis of APTI and Biological and Socio- Economic characters (Noor et al. 2015; Sahu et al. 2020)

Grading Character	**Parameters**	**Pattern of Assessment**	**Grade Alloted**

Tolerance	Air Pollution Tolerance Index	<7	-
		7-9	+
		9-11	++
		11-13	+++
		13-15	++++
		15-17	+++++
Biological and Socio- Economic	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	+
	Hardness	Delineate	-
		Hardy	+
	Economic Value	Less than three uses	-
		Three or four uses	+
		Five or more uses	++

Table 3: Anticipated Performance index (API) of plant species

Grade	**Score (%)**	**Assessment Category**
0	Upto 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

2.3. STATISTICAL ANALYSIS

The APTI values were statistically analyzed using two sample t-test (assuming equal variance) for all the three species to identify whether there is a significance difference between APTI values of industrial setup (Barhi industrial area and rai industrial area) with other setups including urban setup (Ganaur railway station and Sonipat railway station), institutional setup (Dcrust campus, Murthal) and agriculture dominated regions. The statistical assessment shows a significant difference (p=0.0000) in APTI. The significant statistical difference between trees in industrial and other setups indicates that the trees in industrial areas show higher APTI values therefore these trees are preferred for greenbelt planning and urban planning. The green belts occur as a buffer between industrial zones and residential spaces so significant differences in p-value lead planners to choose specific plant species.

3. RESULTS AND DISCUSSIONS

Current study focusses on identifying tolerant species and assess their tolerance potential in varying environmental setups including urban setup (Ganaur railway station and Sonipat railway station), Industrial setup (Barhi industrial area and Rai industrial area), Institutional setup (DCRUST campus), and agricultural setup. The criteria used for identification of tolerant species was calculation of APTI and API. APTI uses four parameters including AA, pH, TCh and RWC for assessment of trees. It has been observed that APTI alone is not adequate for the selection of tolerant species for establishment of green belt development. Therefore, API grade was calculated on the basis of APTI socio-economic and biological characters of trees (Noor et al. 2014). The four important parameters react differently for different environmental setups even if these are assessed for the same species.

Variations in RWC among all setups is given in Table 4. RWC varied significantly from 76.03 ± 5.24% to 83.82 ± 4.72% at all setups. Maximum RWC was recorded 83.82% at agricultural setup for *F. religiosa* and minimum RWC was recorded 76.03% at urban setup (Ganaur Railway Station) in *A. indica*. The values recorded for *A. indica* were 76.03 ± 5.24 %, 76.59 ± 2.61%, 76.86 ± 2.58 %, 77.21 ± 1.65 %, 78.61 ± 4.60 % and 78.23 ± 5.64 % at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively. The values recorded for *F. benghalensis* were 80.76 ± 2.30, 80.06 ± 5.38, 82.45 ± 4.06, 81.01 ± 4.04, 81.46 ± 3.90 and 80.70 ± 12.21 at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively. The values recorded for *F. religiosa* were 82.64 ± 3.33, 83.06 ± 3.83, 83.55 ± 2.82, 83.01 ± 3.12, 83.57 ± 2.69 and 83.82 ± 4.72 at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively. Relative water content (RWC) aids in maintaining physiological balance in trees under stress conditions. Plants with high RWC have higher transpiration rate and are more resilient to pollution (Jyothi et al. 2010). Trees exhibiting higher RWC possess improved water retention capabilities and can support metabolic functions even when water loss is heightened due to pollution (Kamal et al. 2024). A reduction in RWC might signal water stress, potentially resulting in drought-like conditions, even when there is sufficient water available (Zeeshan et al. 2024). A tree's capacity to sustain elevated RWC in the face of pollution stress is frequently a crucial characteristic of its tolerance to pollution (Li et al. 2024). In the present study, the RWC of *A. indica*; *F. benghalensis* and *F. religiosa* in polluted sites was higher indicating that the tree species has adapted effectively. High soil moisture content was also linked to high RWC in leaves (Das et al. 2010; Sahu et al. 2020). Greater RWC indicates a plant's ability to withstand air pollution (Paulsamy et al. 2011). Under stress conditions RWC plays an important role in regulating physiological balance (Tsega et al. 2014). The high RWC in agriculture setup probably may be due to the high soil moisture content (Huang et al. 2020).

Table 4: APTI of *Azadirachta indica*, *Ficus benghalensis* and *Ficus religiosa*

(A= Ascorbic acid content; T= Total Chlorophyll content; P= pH; R= Relative Water content)

Setup	Species	A (mg/gm)	T (mg/gm)	P	R (%)	APTI	Category
Ganaur Railway Station (Urban)	*Azadirachta indica*	9.00 ± 0.39	1.02 ± 0.63	6.41 ± 0.10	76.03 ± 5.24	14.29 ± 0.48	Intermediate Tolerant
	Ficus benghalensis	4.46 ± 0.64	1.20 ± 0.53	8.33 ± 0.12	80.76 ± 2.30	12.30 ± 0.56	Intermediate Tolerant
	Ficus religiosa	4.82 ± 0.63	1.08 ± 0.22	8.25 ± 0.12	82.64 ± 3.33	12.75 ± 0.67	Intermediate Tolerant
Sonipat Railway Station (Urban)	*Azadirachta indica*	8.16 ± 0.54	1.29 ± 0.30	7.73 ± 0.09	76.59 ± 2.61	15.02 ± 0.58	Intermediate Tolerant
	Ficus benghalensis	5.10 ± 0.60	1.55 ± 0.32	7.51 ± 0.08	80.06 ± 5.38	12.63 ± 0.75	Intermediate Tolerant
	Ficus religiosa	5.14 ± 0.62	1.18 ± 0.49	8.40 ± 0.17	83.06 ± 3.83	13.18 ± 0.93	Intermediate Tolerant
DCRUST Campus (Institu-tional)	*Azadirachta indica*	11.73 ± 0.76	0.86 ± 0.42	6.80 ± 0.09	76.86 ± 2.58	16.67 ± 0.74	Intermediate Tolerant
	Ficus benghalensis	5.77 ± 0.74	1.04 ± 0.37	7.39 ± 0.13	82.45 ± 4.06	13.13 ± 0.67	Intermediate Tolerant
	Ficus religiosa	4.78 ± 0.48	0.83 ± 0.21	8.57 ± 0.15	83.55 ± 2.82	12.85 ± 0.57	Intermediate Tolerant
Barhi In-dustrial Area	*Azadirachta indica*	14.08 ± 0.80	1.42 ± 0.27	6.66 ± 0.16	77.21 ± 1.65	19.13 ± 0.93	Tolerant
	Ficus benghalensis	6.81 ± 0.51	1.46 ± 0.27	8.22 ± 0.49	81.01 ± 4.04	14.67 ± 0.3	Intermediate Tolerant
	Ficus religiosa	4.73 ± 0.56	1.17 ± 0.26	7.76 ± 0.42	83.01 ± 3.12	12.52 ± 0.37	Intermediate Tolerant
Rai Indus-trial Area	*Azadirachta indica*	15.75 ± 0.92	1.40 ± 0.37	7.39 ± 0.12	78.61 ± 4.60	21.70 ± 1.08	Tolerant
	Ficus benghalensis	7.23 ± 0.41	1.14 ± 0.74	7.68 ± 0.07	81.46 ± 3.90	14.85 ± 0.75	Intermediate Tolerant
	Ficus religiosa	6.05 ± 0.77	1.42 ± 0.68	8.50 ± 0.15	83.57 ± 2.69	14.50 ± 0.60	Intermediate Tolerant
Agricul-tural	*Azadirachta indica*	12.46 ± 0.77	1.26 ± 0.50	7.61 ± 0.13	78.23 ± 5.64	18.89 ± 0.80	Tolerant
	Ficus benghalensis	4.60 ± 0.67	1.18 ± 0.50	7.79 ± 0.12	80.70 ± 3.67	12.21 ± 0.55	Intermediate Tolerant
	Ficus religiosa	4.29 ± 0.64	1.21 ± 0.27	7.86 ± 0.21	83.82 ± 4.72	12.09 ± 0.57	Intermediate Tolerant

pH varied significantly from 6.41 ± 0.10 to 8.57 ± 0.15 at all setups. Maximum pH was recorded 8.57 at Institutional setup (DCRUST Campus) for *F. religiosa* and minimum pH was recorded 6.41 at urban setup (Ganaur Railway Station) in *A. indica*. The values recorded for *A. indica* were 6.41± 0.10, 7.73 ± 0.09, 6.80 ±

0.09, 6.66 ± 0.16, 7.39 ± 0.12 and 7.61 ± 0.13 at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively. The values recorded for *F. benghalensis* were 8.33 ± 0.12, 7.51 ± 0.08, 7.39 ± 0.13, 8.22 ± 0.49, 7.68 ± 0.07 and 7.79 ± 0.12 at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively. The values recorded for *F. religiosa* were 8.25 ± 0.12, 8.40 ± 0.17, 8.57 ± 0.154, 7.76 ± 0.42, 8.50 ± 0.15 and 7.86 ± 0.21 at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively. Variations in pH among all setups for is given in Table 4. The variability in leaf pH was observed across all the sites. A change in pH can impact the chemical makeup of tree tissues, affecting the availability of nutrients, the absorption of water, and the function of enzymes (Weintraub et al. 2007). Trees that can withstand fluctuations in pH or keep their tissues at an ideal pH are more resilient to pollution (Gopamma et al. 2024). For instance, certain trees may adjust their root exudates to change soil pH or sustain nutrient absorption during stressful conditions (Sun et al. 2024). The difference in leaf pH is resulted from variation in species and other environmental conditions along with air pollutants (Sahu et al. 2020). *A. indica* exhibited both acidic (< 7) and basic (>7) pH. Acidic pH was found at Ganaur railway station, DCRUST Campus, Barhi industrial area while basic pH was found at Sonipat railway station, rai Industrial area, and agricultural setup. Both *F. benghalensis* and *F. religiosa* exhibited basic pH i.e., >7 in all the sites/setups. Leaf pH impacts the synthesis of AA in trees. It is reported that the areas with high pollution show low pH as reported by Dubey et al. (2023). At higher pH the AA content is also higher in trees, which increases tolerance towards air pollution (Sahu et al. 2020; Paulsamy et al. 2009). However, *F. benghalensis* and *F. religiosa* exhibit a contradictory response, where the pH was higher in high polluted areas. The basic pH in Industrial setup for *F. benghalensis* and *F. religiosa* has been reported in the current study and the same results were also reported by Bharti et al. 2018 at Industrial site in Lucknow for *F. religiosa* and *F. benghalensis*. The low pH (for all the target species) at Barhi industrial area is due to high pollution load as reported in CSE INDIA. (2020) and contributes approximately 37% in total pollution loading as compared to Rai industrial area, which contributes only 1% and showed high (basic) pH value.

Variations in TCh among all setups for *A. indica*, *F. benghalensis* and *F. religiosa* is given in **Table 4**. TCh varied significantly from 0.83 ± 0.21 mg/gm to 1.55 ± 0.32 mg/gm at all setups. Maximum TCh was recorded 1.55 mg/gm at urban setup (Sonipat Railway Station) for *F. benghalensis* and minimum TCh was recorded 0.83 at Institutional setup (DCRUST Campus) in *F. religiosa*. The values recorded for *A. indica* were 1.02± 0.63 mg/gm, 1.29 ± 0.30 mg/gm, 0.86 ± 0.42 mg/gm, 1.42 ± 0.27 mg/gm, 1.40 ± 0.37 mg/gm and 1.26 ± 0.50 mg/gm at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively. The values recorded for *F. benghalensis* were 1.20 ± 0.53 mg/gm, 1.55 ± 0.32 mg/gm, 1.04 ± 0.32 mg/gm, 1.04 ± 0.37 mg/gm, 1.46 ± 0.27 mg/gm and 1.18 ± 0.50 mg/gm at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively. The values recorded for *F. religiosa* were 1.08 ± 0.22 mg/gm, 1.18 ± 0.49 mg/gm, 0.83 ± 0.21 mg/gm, 1.17 ± 0.26 mg/gm, 1.42 ± 0.68 mg/gm and 1.21 ± 0.27 mg/gm at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively.

Increase in TCh with increase in pollution indicate plant tolerance and resistance (Singh et al. 2007) In the present study, the species in industrial setup exhibit more chlorophyll than other setups so these species were pollution resistance. Similar results for increase in chlorophyll content in polluted sites in *A. indica*, *F. benghalensis* and *F. religiosa* were observed by Zahid et al. 2023; Sahu et al. 2020; Bharti et al. 2018. Kammerbauer et al. 2000 showed that synthesis of photosynthetically active pigments was increased by 15% due to gaseous exhaust. High values of chlorophyll content in polluted setups might be the reason of higher ascorbic acid content in trees at polluted setups. This is due to the close relationship with the ascorbic acid content, which is mostly concentrated in chloroplasts (Liu et al. 2008). Higher chlorophyll content at the polluted sites is due to mechanism to favour tolerance towards pollution (Ogunkunle et al. 2015). Elevated chlorophyll concentrations assist trees in sustaining photosynthesis even when faced with stress. In environments impacted by pollution, trees may produce extra chlorophyll to offset diminished light absorption or harm inflicted by pollutants (Cessna et al. 2010) . However, a drop in chlorophyll might be a sign of stress and a diminished ability to photosynthesize, which could restrict the tree's ability to grow and reproduce (Sembada et al. 2024).

Photosynthesis was strongly related with pH of leaves and decrease with decrease in leaf pH (Turk et al. 1975). Since both the pH and TCh are highly correlated and differently affected by AA, the pH of the leaf extract (P), and the TCh (T), have been put together and multiplied by the AA content in the suggested APTI formula (Liu et al. 2008).

AA varied significantly from 4.29 ± 0.64 mg/gm to 15.75 ± 0.92 mg/gm at all setups. Maximum AA was recorded 15.75 mg/gm at Rai Industrial area for *A. indica* and minimum AA was recorded 4.29 mg/gm at Agricultural Setup in *F. religiosa*. The values recorded for *A. indica* were 9 ± 0.39 mg/gm, 8.16 ± 0.54 mg/gm, 11.73 ± 0.76 mg/gm, 14.08 ± 0.80 mg/gm, 15.75 ± 0.92 mg/gm and 12.46 ± 0.77 mg/gm at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively. The values recorded for *F. benghalensis* were 4.46 ± 0.64 mg/gm, 5.10 ± 0.60 mg/gm, 5.77 ± 0.74 mg/gm, 6.81 ± 0.51 mg/gm, 7.23 ± 0.41 mg/gm and 4.60 ± 0.67 mg/gm at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively. The values recorded for *F. religiosa* were 4.82 ± 0.63 mg/gm, 5.14 ± 0.62 mg/gm, 4.78 ± 0.48 mg/gm, 4.73 ± 0.56 mg/gm, 6.05 ± 0.77 mg/gm and 4.29 ± 0.64 mg/gm at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively. Variations in AA among all setups is given in Table 4. Ascorbic acid content is higher in industrial setups as AA shows positive relationship with SO2 and NOx. Under pollution stress the production of reactive oxygen species increases the production of AA which in turn scavenges the ROS and prevent the tree from oxidative stress (Bhattacharya et al.2013). Elevated ascorbic acid levels protect essential cellular processes by reducing oxidative damage brought on by contaminants in trees (wang et al. 2012). A tree's ability to prevent or repair damage to its photosynthetic apparatus and other cellular components increases with its antioxidant concentration. Conversely, lower levels of ascorbic acid indicate a diminished ability to fight oxidative stress, making one more vulnerable to harm brought on by pollution (Sharma et al. 2012).

Among all three species *A. indica* has highest AA content. Our results were in agreement with studies conducted by Jain et al.2018; Sahu et al.2020; Prajapati et al. 2008. They found higher values of AA content in *A. indica*. The findings by Gupta et al. 2016; Ogunkunle et al. 2015; Pandey et al. 2015; Rai et al. 2014 suggest that AA content increases with increase in pollution level.

Variations in APTI among all setups for *A. indica*, *F. benghalensis* and *F. religiosa* is given in **Table 4**. APTI varied significantly from 21.70 ± 1.08 to 12.09 ± 0.57 at all setups. Maximum APTI was recorded 21.70 at Rai Industrial Area for *A. indica* and minimum APTI was recorded 12.09 at Agricultural setup in *F. religiosa*. The values recorded for *A. indica* were 14.29 ± 0.48, 15.02 ± 0.58, 16.67 ± 0.74, 19.13 ± 0.93, 21.70 ± 1.08 and 18.89 ± 0.80 at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively. The values recorded for *F. benghalensis* were 12.30 ± 0.56, 12.63 ± 0.75, 13.13 ± 0.67, 14.67 ± 0.3, 14.85 ± 0.75 and 12.21 ± 0.55 at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively. The values recorded for *F. religiosa* were 12.75 ± 0.67, 13.18 ± 0.93, 12.85 ± 0.57, 12.52 ± 0.37, 14.50 ± 0.60 and 12.09 ± 0.57 at Ganaur Railway station, Sonipat Railway station, DCRUST campus, Barhi Industrial area, Rai Industrial area and Agricultural setup respectively.

The APTI values were increased in polluted setups. High APTI value indicates great defense mechanism against air pollution. Various researchers used the APTI to categorized trees into three categories i.e., sensitive, intermediate and tolerant. Trees with APTI values ≤ 11 are categorized as sensitive, 12-16 are considered intermediate and ≥17 is termed as tolerant (Singh et al. 1991). Present findings suggested that *A. indica* is tolerant and *F. benghalensis* and *F. religiosa* are considered intermediately tolerant. Present study showed that *A. indica* was very good performer and *F. benghalensis* and *F. religiosa* are excellent performers at all the setups. **Table 5** shows percentage score and API values of selected trees in different setups.

Table 5: API of different tree species in different environmental setups at district Sonipat

Setup	APTI	Habitat	Canopy	Type	Size	Texture	Hardness	Economic value	Total "+"	% score	API grade	Assessment category
						Azadirachta indica						
Ganaur Railway Station (Urban)	++++	++	++	-	-	-	+	++	11	68.75	4	Good
Sonipat Railway Station (Urban)	+++++	++	++	-	-	-	+	++	12	75	5	Very Good
DCRUST Campus (Institutional)	+++++	++	++	-	-	-	+	++	12	75	5	Very Good
Barhi Industrial Area	+++++	++	++	-	-	-	+	++	12	75	5	Very Good
Rai Industrial Area	+++++	++	++	-	-	-	+	++	12	75	5	Very Good
Agricultural	+++++	++	++	-	-	-	+	++	12	72	5	Very Good
						Ficus benghalensis						
Ganaur Railway Station (Urban)	+++	++	++	+	+	+	+	++	13	81.25	6	Excellent
Sonipat Railway	+++	++	++	+	+	+	+	++	13	81.25	6	Excellent

Station (Urban)												
DCRUST Campus (Institutional)	++++	++	++	+	+	+	+	++	14	87.5	6	Excellent
Barhi Industrial Area	++++	++	++	+	+	+	+	++	14	87.5	6	Excellent
Rai Industrial Area	++++	++	++	+	+	+	+	++	14	87.5	6	Excellent
Agricultural	+++	++	++	+	+	+	+	++	13	81.25	6	Excellent
Ficus religiosa												
Ganaur Railway Station (Urban)	+++	++	++	+	+	+	+	++	13	81.25	6	Excellent
Sonipat Railway Station (Urban)	+++	++	++	+	+	+	+	++	13	81.25	6	Excellent
DCRUST Campus (Institutional)	+++	++	++	+	+	+	+	++	13	81.25	6	Excellent
Barhi Industrial Area	+++	++	++	+	+	+	+	++	13	81.25	6	Excellent
Rai Industrial Area	++++	++	++	+	+	+	+	++	14	87.5	6	Excellent
Agricultural	+++	++	++	+	+	+	+	++	13	81.25	6	Excellent

API accounts for both socio-economic parameters and biochemical parameters. Various parameters including type of plant, leaf size, canopy structure, plant height, plant habit, laminar texture and economic value also contribute to regulate the capacity of the plants to reduce pollution (Prajapati et al. 2008). The API is calculated based on these factors and APTI. Different tree species have different API grades based on these factors. The trees which score the highest API grade can be highly recommended for the development of green belts. The current study showed that *F. benghalensis* and *F. religiosa* are the excellent species and *A. Indica* comes under very good category on the basis of API score. Species with high API grade were recommended for plantation in urban areas due to their high socio-economic and aesthetic value. These species have dense canopy and evergreen and are known for their economic, medicinal and aesthetic values. (Enitan et al. 2022).

Green belt with tolerant tree species acts as natural air filters (Tomson et al. 2021). Greenbelts also serve as cycling and pedestrian corridors promoting active transport while mitigating pollution. (Thompson et al. 2024). In the case of urban planning, vegetative barriers reduce air, pollution and contribute to temperature regulation in the context of urban heat islands (Karimi et al. 2023). These large canopy low maintenance evergreen and semi-evergreen trees contribute to aesthetic value in urban areas and play a vital role in ecosystem services (Liang et al. 2023).

4. CONCLUSIONS

This study clearly reveals that the single biochemical parameter criterion was important in predicting how different tree species responded to air pollution, but it might not be the best option for assessing how plant responds to different contaminants. Our research indicates that choosing the tolerant tree species may be greatly aided by evaluating the API along with APTI. The species with the highest API scores can be recommended for plantation. Among all the three species in six different setups *F. benghalensis* and *F. religiosa* are turned out to be excellent species for plantation on the basis of API. These species can be included in the layout of a greenbelt and urban planning to support industrial regions and urban air pollution control measures. The ground-based study is limited and laborious therefore there is a need for satellite-based approach for estimation of APTI on surrogate variable. The indices should be developed to assess the parameters used in APTI so that it is easy to monitor a large number of species in a short period of time.

Author Contributions: Conceptualization, Dharmendra Singh and Rimpi Antil; methodology, Dharmendra Singh and Rimpi Antil; data curation, Rimpi Antil and Nisha Kumari; writing-original draft, Rimpi Antil; supervision, Nisha Kumari and Dharmendra Singh

Acknowledgments: The authors would like to thank Research Energy Lab, CEEES, DCRUST, Murthal for its support and facilities during research work. Authors would also like to thank Director, HARSAC for providing lab facilities of HARSAC.

Conflicts of Interest: "The authors declare no conflicts of interest."

REFERENCES

1. Alotaibi, M. D., Alharbi, B. H., Al-Shamsi, M. A., Alshahrani, T. S., Al-Namazi, A. A., Alharbi, S. F., Alotaibi, F. S., & Qian, Y., 2020. Assessing the response of five tree species to air pollution in Riyadh City, Saudi Arabia, for potential green belt application. *Environmental Science and Pollution Research*, 27, pp.29156-29170. https://doi.org/10.1007/s11356-020-09226-w
2. Balasubramanian, A., Prasath, C. H., Gobalakrishnan, K., & Radhakrishnan, S., 2018. Air pollution tolerance index (APTI) assessment in tree species of Coimbatore urban city, Tamil Nadu, India. *International Journal of Environment and Climate Change*, 8(1), pp.27-38. https://doi.org/10.9734/ijecc/2018/v8i127106
3. Bharti, S. K., Trivedi, A., & Kumar, N., 2018. Air pollution tolerance index of plants growing near an industrial site. *Urban climate*, 24, pp.820-829. https://doi.org/10.1016/j.uclim.2017.10.007
4. Bhattacharya, T., Kriplani, L., & Chakraborty, S., 2013. Seasonal Variation in Air Pollution Tolerance Index of Various Plant Species of Baroda City. *Universal Journal of Environmental Research & Technology*, 3(2). https://europub.co.uk/articles/-A-31809

5. Centre for Science and Environment (CSE), 2020. Report on assessment of industrial air pollution in Delhi-NCR. Retrieved 12 December 2024 from https://www.cseindia.org/report-on-assessment-of-industrial-air-pollution-in-delhi-ncr-10156.
6. Cessna, S., Demmig-Adams, B. and Adams III, W.W., 2010. Exploring photosynthesis and plant stress using inexpensive chlorophyll fluorometers. *Journal of Natural Resources and Life Sciences Education*, 39(1), pp.22-30. https://doi.org/10.4195/jnrlse.2009.0024u
7. Choudhury, P., Banerjee, D., 2009 Biomonitoring of air quality in the industrial town of Asansol using air pollution tolerance index approach. *Research Journal of Chemistry and Environment*, 13: pp.46–51.Rese Jour of Chemi Envi.pdf
8. Das, S., & Prasad, P., 2010. Seasonal variation in air pollution tolerance indices and selection of plant species for industrial areas of Rourkela. *Indian Journal of Environmental Protection*, 30(12), pp.978-988. http://re.indiaenvironmentportal.org.in/files/air%20pollution%20tolerance.pdf
9. Dohmen, G. P., Koppers, A., & Langebartels, C., 1990. Biochemical response of Norway spruce (Picea abies (L.) Karst.) towards 14-month exposure to ozone and acid mist: effects on amino acid, glutathione and polyamine titers. *Environmental pollution*, 64(3-4), pp.375-383. https://doi.org/10.1016/0269-7491(90)90059-L
10. Dubey, R., Choudhary, A.K., Singh, S., Ajay, A., Kumar, S., Kumar, R., Mondal, S., Singh, V.K., 2023 Assessing the impact of air pollution of trees and crops in Eastern Gangetic plains of India. *Current Science*, 124: pp.956-963. https://doi.org/10.18520/cs/v124/i8/956-963
11. Ebrahimi, P., Shokramraji, Z., Tavakkoli, S., Mihaylova, D., & Lante, A., 2023. Chlorophylls as natural bioactive compounds existing in food by-products: A critical review. *Plants*, 12(7), pp. 1533. https://doi.org/10.3390/plants12071533
12. Enitan, I.T., Durowoju, O.S., Edokpayi, J.N. and Odiyo, J.O., 2022. A review of air pollution mitigation approach using air pollution tolerance index (APTI) and anticipated performance index (API). *Atmosphere*, 13(3), p.374. https://doi.org/10.3390/atmos13030374

13. scobedo, F. J., Wagner, J. E., Nowak, D. J., De la Maza, C. L., Rodriguez, M., & Crane, D. E., 2008. Analyzing the cost effectiveness of Santiago, Chile's policy of using urban forests to improve air quality. *Journal of environmental management*, 86(1), pp.148-157. https://doi.org/10.1016/j.jenvman.2006.11.029
14. González, L., González-Vilar, M., 2001. Determination of Relative Water Content. In: Reigosa Roger, M.J. (eds) *Handbook of Plant Ecophysiology Techniques*. Springer, Dordrecht. pp. 207-212. https://doi.org/10.1007/0-306-48057-3_14
15. Gopamma, D., Kumar, K.S., Srinivas, N., Debnath, S., Ram, A., Kumar, S. and Arunachalam, A., 2024. Air Pollution Tolerance and Carbon Sequestration Potential of Tree Species to Combat Climate Change. In Agroforestry Solutions for Climate Change and Environmental Restoration (pp. 301-319). Singapore: *Springer Nature* Singapore. https://doi.org/10.1007/978-981-97-5004-7_14
16. Gupta, G. P., Kumar, B., & Kulshrestha, U. C., 2016. Impact and pollution indices of urban dust on selected plant species for green belt development: mitigation of the air pollution in NCR Delhi, India. *Arabian Journal of Geosciences*, 9, pp.1-15. http://dx.doi.org/10.1007/s12517-015-2226-4.

17. Huang, Z., Liu, Y., Tian, F. P., & Wu, G. L., 2020. Soil water availability threshold indicator was determined by using plant physiological responses under drought conditions. *Ecological Indicators*, 118, 106740. https://doi.org/10.1016/j.ecolind.2020.106740
18. Jain, S., Bhattacharya, T., & Chakraborty, S., 2019. Comparison of plant tolerance towards air pollution of rural, urban and mine sites of Jharkhand: a biochemical approach to identify air pollutant sink. In Advances in Waste Management: Select Proceedings of Recycle 2016. *Springer Singapore*. Pp. 123-142. https://doi.org/10.1007/978-981-13-0215-2_9
19. Jyothi, S. J., Jaya, D. S., 2010. Evaluation of air pollution tolerance index of selected plant species along roadsides in Thiruvanantapuram, Kerala. *Journal of Environmental Biology*, 31: pp. 379–386. https://jeb.co.in/journal_issues/201005_may10/paper_26.pdf
20. Kamal, M.Z.U., Sarker, U., Roy, S.K., Alam, M.S., Azam, M.G., Miah, M.Y., Hossain, N., Ercisli, S. and Alamri, S., 2024. Manure-biochar compost mitigates the soil salinity stress in tomato plants by modulating the osmoregulatory mechanism, photosynthetic pigments, and ionic homeostasis. *Scientific Reports*, 14(1), p.21929. https://doi.org/10.1038/s41598-024-73093-5
21. Kammerbauer, J., & Dick, T., 2000. Monitoring of urban traffic emissions using some physiological indicators in Ricinus communis L. plants. *Archives of Environmental Contamination and Toxicology*, 39, pp.161-166. https://doi.org/10.1007/s002440010092.
22. Karimi, A., Mohammad, P., García-Martínez, A., Moreno-Rangel, D., Gachkar, D. and Gachkar, S., 2023. New developments and future challenges in reducing and controlling heat island effect in urban areas. *Environment, Development and Sustainability*, 25(10), pp.10485-10531. https://doi.org/10.1007/s10668-022-02530-0
23. Liang, D. and Huang, G., 2023. Influence of urban tree traits on their ecosystem services: a literature review. *Land*, 12(9), p.1699. https://doi.org/10.3390/land12091699
24. Li, H., Zhu, X., Kong, W., Zheng, M., Guo, X., & Wang, T., 2023. Physiological response of urban greening shrubs to atmospheric particulate matter pollution: An integral view of ecosystem service and plant function. *Environmental and Experimental Botany*, 213, 105439. https://doi.org/10.1016/j.envexpbot.2023.105439
25. Li, S., Li, S., Agathokleous, E., Hao, G., Wang, S. and Feng, Z., 2024. Leaf water relations determine the trade-off between ozone resistance and stomatal functionality in urban tree species. *Plant, Cell & Environment*, 47(8), pp.3166-3180. https://doi.org/10.1111/pce.14934
26. Liu, Y. J., & Ding, H. U. I., 2008. Variation in air pollution tolerance index of plants near a steel factory: implication for landscape-plant species selection for industrial areas. *WSEAS Transactions on Environment and development*, 4(1), pp.24-32. http://www.wseas.us/e-library/transactions/environment/2008/25-598N.pdf
27. Mondal, D., Gupta, S., & Datta, J. K., 2011. Anticipated performance index of some tree species considered for green belt development in an urban area. *International Research Journal of Plant Science*, 2(4), pp.99-106. http://www.interesjournals.org/IRJPS
28. Moore, P.D., Chapman, S.B., 1986. Methods in plant ecology. Blackwell Scientific Publications, Oxford, pp 1–580 29.
29. Murthy, B. S., Latha, R., Tiwari, A., Rathod, A., Singh, S., & Beig, G. (2020). Impact of mixing layer height on air quality in winter. *Journal of Atmospheric and Solar-Terrestrial Physics*, 197, 105157. https://doi.org/10.1016/j.jastp.2019.105157

30. TCP (Department of Town and Country Planning) Haryana. Preparation of Sub Regional Plan for Haryana Sub-Region of NCR-2021: Interim Report -II. Chapter 13: [Land Use]. Retrieved 18 February 2025 from https://tcpharyana.gov.in/ncrpb/13.chapter13.pdf
31. Noor, M. J., Sultana, S., Fatima, S., Ahmad, M., Zafar, M., Sarfraz, M., ... & Ashraf, M. A., 2015. Retracted Article: Estimation of anticipated performance index and air pollution tolerance index and of vegetation around the marble industrial areas of Potwar region: bioindicators of plant pollution response. *Environmental Geochemistry and Health*, 37, pp.441-455. https://doi.org/10.1007/s10653-014-9657-9
32. Ogunkunle, C. O., Suleiman, L. B., Oyedeji, S., Awotoye, O. O., & Fatoba, P. O., 2015. Assessing the air pollution tolerance index and anticipated performance index of some tree species for biomonitoring environmental health. *Agroforestry Systems*, 89, pp.447-454. https://doi.org/10.1007/s10457-014-9781-7
33. Pandey, A. K., Pandey, M., Mishra, A., Tiwary, S. M., & Tripathi, B. D., 2015. Air pollution tolerance index and anticipated performance index of some plant species for development of urban forest. *Urban Forestry & Urban Greening*, 14(4), pp.866-871. http://dx.doi.org/10.1016/j.ufug.2015.08.001
34. Paulsamy, S., & Senthilkumar, P., 2011. Evaluation of air pollution tolerant tree species for Kothagiri Municipal Town, the Nilgiris, Tamil Nadu. *Journal of Research in Biology*, 1(2), pp.148-152.Retrieved from https://ojs.jresearchbiology.com/index.php/jrb/article/view/57
35. Paulsamy, S. and Senthilkumar, P., 2009. Identification of air pollution tolerant tree species for the industrial city, Tirupur, Tamil Nadu. *Nature Environment and Pollution Technology*, 8(3), pp.585-8. https://neptjournal.com/upload-images/NL-5-31-(31)B-1370com.pdf
36. Pradhan, A. A., Pattanayak, S. K., Bhadra, A. K., & Ekka, K., 2016. Air pollution tolerance index of three tree species along national high way-6 between Ainthapalli to Remed, Sambalpur District, Western Odisha, India. *Biolife*, 4(1), pp.111-120. doi:10.17812/blj.2016.4116
37. Prajapati, S. K., & Tripathi, B. D., 2008. Anticipated Performance Index of some tree species considered for green belt development in and around an urban area: A case study of Varanasi city, India. *Journal of environmental management*, 88(4), pp.1343-1349. https://doi.org/10.1016/j.jenvman.2007.07.002
38. Rai, P.K. and Panda, L.L., 2014. Dust capturing potential and air pollution tolerance index (APTI) of some road side tree vegetation in Aizawl, Mizoram, India: an Indo-Burma hot spot region. *Air Quality, Atmosphere & Health*, 7, pp.93-101. https://doi.org/10.1007/s11869-013-0217-8
39. Raza, S. H., Murthy, M. S. R., & Adeel Ahmed, A. A., 1988. Air pollution tolerance index of certain plants of Nacharam Industrial Area, Hyderabad. *Indian Journal of botany*, 11(1), pp.91-95. https://www.cabidigitallibrary.org/doi/full/10.5555/19900639188
40. Roy, A., Bhattacharya, T., & Kumari, M., 2020. Air pollution tolerance, metal accumulation and dust capturing capacity of common tropical trees in commercial and industrial sites. *Science of the Total Environment*, 722, 137622. https://doi.org/10.1016/j.scitotenv.2020.137622
41. Roy, A., Mandal, M., Das, S., Popek, R., Rakwal, R., Agrawal, G. K., Awasthi, A., & Sarkar, A., 2024. The cellular consequences of particulate matter pollutants in plants: Safeguarding the harmonious integration of structure and function. *Science of the Total Environment*, 169763. https://doi.org/10.1016/j.scitotenv.2023.169763

42. Sahu, C., Basti, S., & Sahu, S. K., 2020. Air pollution tolerance index (APTI) and expected performance index (EPI) of trees in Sambalpur town of India. *SN Applied Sciences*, 2(8), 1327. https://doi.org/10.1007/s42452-020-3120-6
43. Sharma, M., Panwar, N., Arora, P., Luhach, J., & Chaudhry, S., 2013. Analysis of biological factors for determination of air pollution tolerance index of selected plants in Yamuna Nagar, India. *Journal of environmental biology*, 34(3), 509. https://www.jeb.co.in/journal_issues/201305_may13/paper_02.pdf
44. Sharma, P., Jha, A.B., Dubey, R.S. and Pessarakli, M., 2012. Reactive oxygen species, oxidative damage, and antioxidative defense mechanism in plants under stressful conditions. *Journal of botany*, 2012(1), p.217037. https://doi.org/10.1155/2012/217037
45. Sembada, A.A., Faizal, A. and Sulistyawati, E., 2024. Photosynthesis efficiency as key factor in decision-making for forest design and redesign: A systematic literature review. *Ecological Frontiers*,44(6),pp.1128-1139. https://doi.org/10.1016/j.ecofro.2024.07.008
46. Simon, E., Molnár, V. É., Lajtos, D., Bibi, D., Tóthmérész, B., & Szabó, S., 2021. Usefulness of tree species as urban health indicators. *Plants*, 10(12), 2797. https://doi.org/10.3390/plants10122797
47. Singh, S. K., & Rao, D. N., (1983, November). Evaluation of plants for their tolerance to air pollution. In Proceedings of symposium on air pollution control (Vol. 1, No. 1, pp. 218-224).
48. Singh, S. K., Rao, D. N., Agrawal, M., Pandey, J., & Naryan, D. (1991). Air pollution tolerance index of plants. *Journal of Environmental Management*, 32(1), pp.45-55. https://doi.org/10.1016/S0301-4797(05)80080-5
49. Singh, S., Verma, A. (2007). Phytoremediation of Air Pollutants: A Review. In: Singh, S.N., Tripathi, R.D. (eds) Environmental Bioremediation Technologies. Springer, Berlin, Heidelberg. pp. 293-314. https://doi.org/10.1007/978-3-540-34793-4_13
50. Steubing, L., Fangmeier, A., Both, R., & Frankenfeld, M. (1989). Effects of SO2, NO2, and O3 on population development and morphological and physiological parameters of native herb layer species in a beech forest. *Environmental pollution*, 58(4), pp. 281-302. https://doi.org/10.1016/0269-7491(89)90140-1
51. Sumathi, R. and Sriram, G., 2023. Comparison of Machine Learning Models in the Prediction of Accumulation of Heavy Metals in the Tree Species in Kanchipuram, Tamilnadu. *Nature Environment and Pollution Technology*, 22(2), pp.853-860. 10.46488/NEPT. 2023.v22i02.027
52. Sun, W., Li, Q., Qiao, B., Jia, K., Li, C. and Zhao, C., 2024. Advances in plant–soil feedback driven by root exudates in forest ecosystems. *Forests*, 15(3), p.515. https://doi.org/10.3390/f15030515
53. Thompson, O.P., Kosoe, E.A. and Xu, J., 2024. Green Infrastructure and Urban Planning for Sustainable Clean Air. In Sustainable Strategies for Air Pollution Mitigation: Development, Economics, and Technologies (pp. 343-375). *Cham*: Springer Nature Switzerland. https://doi.org/10.1007/698_2024_1122
54. Tomson, N., Michael, R.N. and Agranovski, I.E., 2021. Removal of particulate air pollutants by Australian vegetation potentially used for green barriers. *Atmospheric Pollution Research*, 12(6), p.101070. https://doi.org/10.1016/j.apr.2021.101070
55. Tsega, Y. C., & Prasad, A. D. (2014). Variation in air pollution tolerance index and anticipated performance index of roadside plants in Mysore, India. *Journal of Environmental Biology*, 35(1), pp.185-190. https://jeb.co.in/journal_issues/201401_jan14/paper_05.pdf

56. Türk, R., & Wirth, V. (1975). The pH dependence of SO 2 damage to lichens. *Oecologia*, 19, pp.285-291. https://doi.org/10.1007/BF00348104
57. Wang, S., Liang, D., Li, C., Hao, Y., Ma, F. and Shu, H., 2012. Influence of drought stress on the cellular ultrastructure and antioxidant system in leaves of drought-tolerant and drought-sensitive apple rootstocks. *Plant Physiology and Biochemistry*, 51, pp.81-89. https://doi.org/10.1016/j.plaphy.2011.10.014
58. Weatherley, P.E., 1951. Studies in the water relations of the cotton plant. II. Diurnal and seasonal variations in relative turgidity and environmental factors. *The New Phytologist*, 50(1), pp.36-51.https://doi.org/10.1111/j.1469-8137.1951.tb05168.x
59. Weintraub, M.N., Scott-Denton, L.E., Schmidt, S.K. and Monson, R.K., 2007. The effects of tree rhizodeposition on soil exoenzyme activity, dissolved organic carbon, and nutrient availability in a subalpine forest ecosystem. *Oecologia*, 154, pp.327-338. https://doi.org/10.1007/s00442-007-0804-1
60. Yadav, R. and Pandey, P., 2020. Assessment of Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API) of roadside plants for the development of greenbelt in urban area of Bathinda City, Punjab, India. *Bulletin of Environmental Contamination and Toxicology*, 105(6), pp.906-914. https://doi.org/10.1007/s00128-020-03027-0
61. Yu, M., Zhou, W., Zhao, X., Liang, X., Wang, Y., & Tang, G. (2022). Is urban greening an effective solution to enhance environmental comfort and improve air quality? *Environmental Science & Technology*, 56(9), pp. 5390-5397. https://doi.org/10.1021/acs.est.1c07814
62. Zahid, A., Ali, S., Anwar, W., Fatima, A., Chattha, M. B., Ayub, A., Raza, A., Ali, K., & Siddique, M. (2023). Assessing the air pollution tolerance index (APTI) of trees in residential and roadside sites of Lahore, Pakistan. *SN Applied Sciences*, 5(11), 294. https://doi.org/10.1007/s42452-023-05470-0
63. Zeeshan, M., Wang, X., Salam, A., Wu, H., Li, S., Zhu, S., Chang, J., Chen, X., Zhang, Z. and Zhang, P., 2024. Selenium nanoparticles boost the drought stress response of soybean by enhancing pigment accumulation, oxidative stress management and ultrastructural integrity. *Agronomy*, 14(7), p.1372. https://doi.org/10.3390/agronomy14071372