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Integrating APTI, API and Biochemical Traits to Assess Pollution Tolerance of Ornamental Trees in High-traffic Urban Environments

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ABSTRACT

Background: Rapid urbanization and vehicular emissions have increased air pollution in urban environments, necessitating the development of sustainable green belts using pollution-tolerant ornamental tree species. The present study aimed to assess the pollution sensitivity and adaptability of ornamental tree species under high traffic environments for sustainable green belt development.

Methods: The present study was conducted during 2025-26 at SRM Institute of Science and Technology, Kattankulathur, Chengalpattu, Tamil Nadu. Twenty ornamental tree species were evaluated under high-traffic environments. A comprehensive survey was conducted using stratified random sampling to identify and catalogue the species present in these environments. The experiment followed a completely randomized design (CRD). Morphological, physiological and biochemical parameters including dust accumulation, Total chlorophyll content, Relative water content (RWC), Ascorbic acid, pH and Air Pollution Tolerance Index (APTI) were analyzed. Correlation analysis was also performed to determine the relationship between APTI and biochemical parameters.

Result: Trees with dense canopies, pinnately arranged leaves and smoother surfaces exhibited greater resistance to pollution stress. *Ficus religiosa* had the highest dust accumulation capacity (0.513), followed by *Delonix regia* (0.427) and *Azadirachta indica* (0.414). All three were categorized as extremely tolerant (18.1-21.0) by APTI values of 20.10, 19.76 and 19.39, respectively. Strong positive correlations between chlorophyll, APTI and RWC were confirmed by correlation analysis.

Key words: Elevated traffic load, Morphological, Physicochemical changes, Pollution tolerance, Semi-urban, Tree species.

INTRODUCTION

Urban pollution poses severe threats to both environmental integrity and public health, particularly in densely populated cities. As per the “Revision of World Urbanization Prospects,” the global urban population currently stands at 55 per cent and is projected to reach 68 per cent by 2050 (UN, 2019). Particulate matter (PM), adversely affects plant growth by inducing oxidative stress and disrupting physiological processes (Yadav *et al.,* 2019). Rapid urbanization has intensified vehicular emissions and declined sustainable energy use, escalating particulate matter and harmful gas concentrations across residential, institutional and recreational spaces (Shrestha *et al.,* 2021). Vehicular emissions release particulate matter, heavy metals and toxic gases that adversely affect air quality, soil health and plant physiological processes (Dizaji *et al.,* 2016). Increasing population growth, industrialization and infrastructure development exert significant pressure on natural resources, leading to the loss of productive agricultural land and environmental degradation (Radhika *et al.,* 2026). Among natural mitigation strategies, vegetation stands out as the most effective biological solution. Plants uniquely eliminate suspended particulate matter (SPM), making green spaces indispensable in urban planning (Singh *et al.*, 2021; Chaurasia *et al.,* 2022; Patel *et al.,* 2023; Sapkota and Shrestha 2024). Prolonged pollution exposure triggers measurable physiological changes in plants, including chlorophyll content, ascorbic acid, relative water content and carotenoid levels, serving as reliable bioindicators (Sapkota and Shrestha, 2024). The air pollution

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tolerance index (APTI) effectively quantifies species-level pollution tolerance (Leghari *et al.,* 2019). This study addresses the estimation of APTI and the anticipated performance index (API) to evaluate tree species under varying traffic conditions, distinguishing sensitive bio-indicator species from tolerant pollutant sinks (Correa-Ochoa *et al.,* 2022). Hence, the present study is conducted to identify suitable ornamental tree species for urban green belt development.

MATERIALS AND METHODS

The present study was conducted at SRM Institute of Science and Technology, Kattankulathur, Chengalpattu, Tamil Nadu, during the year 2025-2026. The investigation focused on assessing air pollution levels, particularly PM_{10}, in high-traffic zones such as the premises of SRM Lake, Valliammai Engineering College entrance and Golden Arch gate. PM_{10} concentrations were monitored using a high-volume air sampler in two 12-hour intervals. A comprehensive tree survey recorded 22,928 trees belonging to 70 species, of which twenty predominant species (Table 1) were selected for detailed morphological, socioeconomic and biochemical analysis of leaf samples (Rajakaruna and Masakorala, 2019).

The Dust capturing capacity (DCC) on leaf samples was estimated using the gravimetric method suggested by Manisha and Pal (2014). The leaf extract pH was determined by the ratio of adsorbed hydrogen to metallic ions, indicating its acidity or alkalinity (Sadasivam and Manickam, 2005). The method described by Henson *et al.* (1981) was utilized to determine the relative water content. The total chlorophyll concentration was estimated using Arnon (1949) approach. Ascorbic acid was measured using the Ranganna (1986) method and reported as mg g^{-1}. The ability of the tree species to withstand air pollution was estimated by the method outlined by Singh and Rao (1983). The APTI is calculated using the formula.

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

Where,

A = Ascorbic acid content (mg/g).

T = Total chlorophyll content (mg/g).

R = Relative water content.

P = pH of the leaf extract.

The APTI of each selected species was combined with morphological plant traits, such as plant habit, canopy structure and plant type, to determine the API. The chosen plant species is given an API score as prescribed by Prajapati and Tripathi (2008) (Table 2). The formula used to determine the percentage score is (Table 3):

$$API = \frac{\text{No. of grade (+) obtained by any tree species}}{\text{Maximum possible number of (+) of any tree species}} \times 100$$

Particulate matter was assessed by measuring the concentration of PM_{10} (Particulate Matter $\leq$10).

Table 1: General description of selected ornamental tree species.

Common name	Scientific name	Family	Origin
Silk cotton tree	*Bombax ceiba*	Malvaceae	Tropical Asia
Neem tree	*Azadirachta indica*	Meliaceae	India
Butterfly tree	*Bauhinia purpurea*	Fabaceae	Southeastern Asia
Bottle brush	*Callistemon citrinus*	Myrtaceae	Australia
Amaltas	*Cassia fistula*	Fabaceae	India
Gulmohar	*Delonix regia*	Fabaceae	Madagascar
Weeping fig	*Ficus benjamina*	Moraceae	Southeast Asia
Chinese banyan tree	*Ficus microcarpa*	Moraceae	Tropical and Subtropical Asia
Natal fig	*Ficus natalensis*	Moraceae	Tropical Africa
Peepal tree	*Ficus religiosa*	Moraceae	India
Indian ash tree	*Lannea coromandelica*	Anacardiaceae	Southeast Asia
Copper pod tree	*Peltophorum pterocarpum*	Fabaceae	Indo-China
Cabbage Tree	*Pisonia grandis*	Nyctaginaceae	Indo-Pacific Region
Fiddle leaf plumeria	*Plumeria pudica*	Apocynaceae	South and Central America
Pagoda tree	*Plumeria rubra*	Apocynaceae	Mexico, Central Americ and Venezuela
Pungam tree	*Pongamia pinnata*	Fabaceae	India
Rain tree	*Samanea saman*	Fabaceae	NorthernSouth America/ Central America
Ashoka tree	*Saraca asoca*	Fabaceae	India
Arjun tree	*Terminalia arjuna*	Combretaceae	India
Indian almond	*Terminalia catappa*	Combretaceae	Asia-Pacific region

The concentration of (PM_{10}) in ambient air was calculated using the equation, as suggested by CPCB (2013) at the elevated traffic zone:

$$PM_{10}\,(\mu g/m^3) = \frac{(W_f - W_i)}{V_{air}} \times 10^6$$

Whereas,

W_f = Final weight of filter paper after sampling in g.

W_i = Initial weight of the filter paper before sampling in g.

(W_f=W_i) = Total mass of collected particles in g.

10^6 = Factor for conversion of g to µg.

V_{air} = Volume of air sampled (m^3).

V_{air} is calculated by the average flow rate (Q_{avg} in m^3/hour) and during the time (t-total sampling time in hours) *i.e.*

$$V_{air} = Q_{avg} \times t$$

Table 2: Plant species anticipated performance index (API) grading system.

Grade	Score (%)	Assessment category
0	Up to 30	Not recommended
1	30 to 40	Very poor
2	41 to 50	Poor
3	51 to 60	Moderate
4	61 to 70	Good
5	71 to 80	Very good
6	81 to 90	Excellent
7	91 to 100	Best

Statistical analysis

Data were analysed using CRAN R (Version 4.5.3) and MS Excel 2013. A completely randomized design with three replications was used for statistical analysis. One-way ANOVA with LSD post-hoc test ($p<0.05$) compared treatment means. Pearson's correlation and Principal Component Analysis (PCA) were evaluated between biochemical parameters.

RESULTS AND DISCUSSION

Pollution concentrations

PM_{10} concentrations in the high-traffic zone exhibited significant temporal and seasonal variations throughout the study period (Table 4). During March 2026, daytime PM_{10} concentrations reached 169.35 µg/m^3, whereas nighttime concentrations decreased to 28.97 µg/m^3, likely due to rainfall, increased humidity and reduced anthropogenic activity. In April 2026, comparatively lower PM10 concentrations were observed during both daytime and nighttime (12.70-10.32 µg/m^3). Elevated daytime concentrations were primarily associated with vehicular emissions, construction activities and open burning practices.

Dust capturing capacity (DCC)

DCC showed variations among selected ornamental tree species under elevated traffic environments (Table 5).

Table 3: APTI standards and plant species grades based on physical and socioeconomic significance (Kaur and Nagpal, 2017).

Character grade	Parameter	Assessment pattern	Assigned grade
Tolerance	APTI (Tolerance)	9.0-12.0	+
		12.1-15.0	++
		15.1-18.0	+++
		18.1-21.0	++++
		21.1-24.0	+++++
Biological and socio-economic	Plant habit	Small	-
		Medium	+
		Large	++
	Canopy structure	Globular, irregular and sparse	-
		Open, semi-dense and spreading crowns	+
		Spreading dense	++
	Type of plant	Deciduous	-
		Evergreen	+
Laminar structure	Leaf size	Small	-
		Medium	+
		Large	++
	Texture	Smooth	-
		Coriaceous	+
	Hardiness	Delineate	-
		Hardy	+
	Economic value	Less than three uses	-
		Three or four uses	+
		Five or more uses	++

Maximum grades scored by any plant can be= 16.

DCC of the studied species ranged from 0.102 mg/cm^2 in *Terminalia arjuna* (Lowest) to 0.513 mg/cm^2 in *Ficus religiosa* (Highest). The following trend in the dust-capturing capacity was noted: *Ficus religiosa>Delonix regia> Azadirachta indica>Cassia fistula>Pongamia pinnata> Saraca asoca>Pisonia grandis>Ficus microcarpa> Bombax ceiba>Ficus benjamina>Ficus natalensis> Samanea saman>Plumeria pudica>Plumeria rubra> Callistemon citrinus>Terminalia arjuna*. Rough leaf surfaces and shorter petioles significantly enhanced particle retention in superior species. These findings are confirmed by the previous study (Bharti *et al.*, 2017).

Tolerance index of selected tree species towards air pollution

APTI was estimated and presented in Table 5. *Ficus religiosa* (20.10), *Delonix regia* (19.76) and *Azadirachta indica* (19.39) exhibited the highest pollution tolerance, which may be due to robust antioxidant defenses and effective leaf tissue buffering, making them ideal for urban greening initiatives (Akilan and Nandhakumar, 2016; Correa-Ochoa *et al.,* 2022). *Cassia fistula* demonstrated moderate tolerance, whereas *Termialia catappa*, *Pongamia pinnata* and *Saraca asoca* displayed intermediate tolerance. Twelve species were categorized as sensitive bio-indicators. On the whole, the metabolic characteristics significantly influenced the APTI values (Anake *et al.,* 2022).

Performance of tree species in relation to air pollution

The API evaluates a plant's green belt suitability by incorporating ecological, socioeconomic and biological characteristics (Pathak *et al.,* 2011). Among the species evaluated, API grades ranging from 1 to 6. *Ficus religiosa* (87.50%), *Azhadirachta indica* and *Delonix regia* (81.25%) attained the highest grade (6), reflecting superior pollution tolerance (Table 6). *Cassia fistula*, *Ficus microcarpa*, *Ficus natalensis*, *Pongamia pinnata* and *Terminalia catappa* (62.50% each) were rated "Good" with Grade 4, whereas *Peltophorum pterocarpum* (56.25%) demonstrated moderate tolerance with Grade 3. Species including *Bauhinia purpurea*, *Bombax ceiba*, *Ficus benjamina* and *Samanea saman* ranked as "Poor," with certain others classified as "Very Poor". These outcomes corroborate earlier findings (Pandey, 2015; Patel *et al.,* 2023), reinforcing API's effectiveness as a tool for species selection in urban greening and pollution mitigation efforts.

Table 4: Variations in air pollution concentrations.

Site	PM_{10} (µg/m^3)	
	March 2026	April 2026
Incident 1 (Day time)	169.35	12.70
Incident 2 (Night time)	28.97	10.32

Principal component analysis (PCA)

The PCA biplot revealed substantial biochemical variation among ornamental tree species in high-traffic areas (Fig 1). PC1 and PC2 together accounted for 75.1% of the total variance (49.7% and 25.4%, respectively). PC1 showed strong positive correlations among chlorophyll content, RWC and ascorbic acid. *Delonix regia*, *Ficus religiosa* and *Azadirachta indica* demonstrated superior pollution tolerance, while species like *Pongamia pinnata* excelled in water retention. PC2 highlighted leaf pH differences, with *Bombax ceiba* and others showing strong acid-buffering ability. Several species exhibited poor stress resilience. These findings corroborate established research on urban plant functional responses to pollution gradients (Zhu and Xu, 2021).

Correlation matrix between APTI and biochemical parameters

Significant correlations between APTI and key tree biochemical characteristics were identified through correlation matrix analysis (Table 7). Chlorophyll content showed strong positive associations with both RWC (r= 0.737, p<0.001) and APTI (r= 0.731, p≤0.001), highlighting its role in pollution tolerance. RWC also exhibited a strong

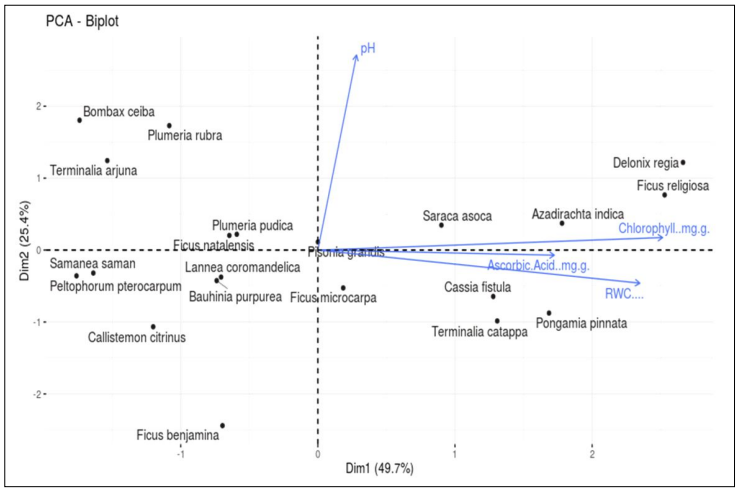


Fig 1: PCA biplot showing relationships among biochemical parameters of selected tree species.

Table 5: Assessment of APTI scores based on biological, socioeconomic and laminar characteristics.

Scientific name	APTI grade	APTI value	Biological and socio-economic			Laminar		Hardiness	Economic value	Grade		Dust capturing capacity (mg/cm^2)
			Plant habit	Canopy structure	Type of plant	Leaf size	Texture			Total % plus (+)	Scoring	
Azadirachta indica	++++	19.39	++	+	+	++	-	+	++	13	81.25%	0.414^{bc}
Bauhinia purpurea	+	9.79	++	+	-	+	-	-	++	7	43.75%	0.156^{kl}
Bombax ceiba	+	11.02	++	-	-	++	-	-	++	7	43.75%	0.215^{gh}
Callistemon citrinus	+	9.59	++	-	+	+	-	-	++	7	43.75%	0.124^{mn}
Cassia fistula	+++	15.72	++	+	-	+	-	+	++	10	62.50%	0.386^{cd}
Delonix regia	++++	19.76	++	++	-	++	-	+	++	13	81.25%	0.427^{b}
Ficus benjamina	+	11.38	-	++	+	++	-	-	++	8	50.00%	0.216^{gh}
Ficus microcarpa	+	11.39	-	++	+	++	+	+	++	10	62.50%	0.239^{fg}
Ficus natalensis	+	10.64	++	++	+	-	+	+	++	10	62.50%	0.208^{hi}
Ficus religiosa	++++	20.1	++	++	-	++	+	+	++	14	87.50%	0.513^{a}
Lannea coromandelica	+	9.99	-	+	-	+	-	-	++	5	31.25%	0.168^{jk}
Peltophorum pterocarpum	+	9.69	++	+	-	++	-	+	++	9	56.25%	0.133^{lm}
Pisonia grandis	+	11.72	-	++	+	+	-	+	+	7	43.75%	0.263^{ef}
Plumeria pudica	+	10.27	++	+	+	-	-	-	++	7	43.75%	0.184^{ijk}
Plumeria rubra	+	10.02	+	-	-	+	-	+	++	6	37.50%	0.176^{jk}
Pongamia pinnata	++	13.15	++	++	+	+	-	-	++	10	62.50%	0.279^{e}
Samanea saman	+	10.59	++	++	-	++	-	+	–	8	50.00%	0.195^{hij}
Saraca asoca	++	12.5	++	-	+	+	-	-	++	8	50.00%	0.273^{e}
Terminalia arjuna	+	9.11	-	+	-	++	-	+	++	7	43.75%	0.102^{n}
Terminalia catappa	++	13.94	++	+	-	++	-	+	++	10	62.50%	0.366^{d}

Values followed by different superscript letters within a column differ significantly at P<0.05 according to LSD test.

Table 6: Anticipated performance Index (API) value of the selected tree species.

Scientific name	Grade		API values	Assessment
	Total plus (+)	% Score		
Azadirachta indica	13	81.25%	6	Excellent
Bauhinia purpurea	7	43.75%	2	Poor
Bombax ceiba	7	43.75%	2	Poor
Callistemon citrinus	7	43.75%	2	Poor
Cassia fistula	10	62.50%	4	Good
Delonix regia	13	81.25%	6	Good
Ficus benjamina	8	50.00%	2	Poor
Ficus microcarpa	10	62.50%	4	Good
Ficus natalensis	10	62.50%	4	Good
Ficus religiosa	14	87.50%	6	Excellent
Lannea coromandelica	5	31.25%	1	Very Poor
Peltophorum pterocarpum	9	56.25%	3	Moderate
Pisonia grandis	7	43.75%	2	Poor
Plumeria pudica	7	43.75%	2	Poor
Plumeria rubra	6	37.50%	1	Very Poor
Pongamia pinnata	10	62.50%	4	Good
Samanea saman	8	50.00%	2	Poor
Saraca asoca	8	50.00%	2	Poor
Terminalia arjuna	7	43.75%	2	Poor
Terminalia catappa	10	62.50%	4	Good

Table 7: The matrix of Pearson's correlation coefficient (r) between biochemical parameters and APTI.

	Chlorophyll (mg/g)	RWC (%)	Ascorbic acid (mg/g)	pH	APTI value
Chlorophyll (mg/g)	1	0.737***	0.415	0.137	0.731***
RWC (%)	0.737***	1	0.279	-0.043	0.626**
Ascorbic acid (mg/g)	0.415	0.279	1	0.02	0.871***
pH	0.137	-0.043	0.02	1	0.247
APTI value	0.731***	0.626**	0.871***	0.247	1

***Significant at the two-tailed p<0.001 level.

**Significant at the two-tailed p<0.01 level.

*Significant at the two-tailed p<0.05 level.

positive correlation with APTI (r= 0.626, p≤0.01). Ascorbic acid demonstrated the strongest positive correlation with APTI (r= 0.871, p<0.001), confirming its critical role in oxidative stress reduction, while its associations with RWC (r= 0.279) and chlorophyll (r= 0.415) were moderate and non-significant. pH showed weak, non-significant relationships with all parameters, including APTI (r= 0.247). These findings underscore the importance of Ascorbic acid, RWC and Chlorophyll in determining APTI and consistent with previous studies (Enitan *et al.,* 2022; Kaur and Nagpal 2017; Ashick Rajah *et al.,* 2025) and findings of Sabitha and Thambavani (2011), who reported significant positive correlations among chlorophyll, ascorbic acid and APTI.

CONCLUSION

This study demonstrated significant interspecific variation in physiological, morphological and biochemical responses of twenty ornamental tree species to traffic-induced dust pollution. *Ficus religiosa*, *Delonix regia* and *Azadirachta indica* recorded the highest APTI values, with *Azadirachta indica* showing superior API performance. These species, along with others, are recommended for greenbelt development in high-traffic areas to enhance air quality and ecological sustainability.

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Disclaimers

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Informed consent statement

None.

Conflict of interest

The authors declare no conflicts of interest.

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