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Seasonal Variations in Air Pollution Tolerance Index (APTI) of Selected Avenue Tree Species in Bhubaneswar, Odisha

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Abstract: The study examines spatial and seasonal variations in the air pollution tolerance index (APTI) of four tree species (*Ficus religiosa*, *Polyalthia longifolia*, *Syzygium cumini,* and *Lagerstroemia speciosa)* across three sites (industrial, traffic, and natural forest area) in Bhubaneswar city of Odisha. Significant variations in leaf biochemical parameters (leaf pH, ascorbic acid, total chlorophyll, and relative water content) were observed among species, depending on site conditions and seasons. The calculated APTI value (using four biochemical parameters) inferred *P. longifolia* as tolerant (33.97), *F. religiosa* moderately tolerant (22.07 to 25.46) towards air pollution. Conversely, *S. cumini* and *L. speciosa* showed lower APTI value, indicating their sensitivity to the polluted environment. Irrespective of species, pollution tolerance was higher in the rainy season than in the winter and summer seasons. Pearson's correlation study revealed that leaf relative water content and ascorbic acid enhance the tree's defence against pollution-induced oxidative stress. Study suggest *P. longifolia* and *F. religiosa* are best for urban afforestation, avenue plantation, and air pollution control management in Bhubaneswar.

Keywords: Leaf pH, Ascorbic acid, Chlorophyll, Relative water content, Urban green belt, Avenue plantation

Air pollution has emerged as a significant environmental and public health concern in India, affecting not only major metropolitan centers but also medium and smaller towns with increasing severity. This pervasive degradation in air quality is an inevitable result of rapid industrialization and unplanned urban expansion. Rapid population growth, trade liberalization, rising vehicular emissions, and industrialization have collectively intensified atmospheric pollutants, especially oxides of sulphur (SO_x), nitrogen (NO_x), volatile organic compounds (VOCs), and trace metals (Shaheen et al., 2025). The relentless emission of harmful gases and fine particulates poses a significant threat to air quality, profoundly impacting human health, ecosystem stability, and overall quality of life on Earth (Lohwasse et al., 2025). Addressing this environmental crisis is imperative for protecting public health and ensuring a sustainable future for posterity.

Trees play a crucial role in improving air quality by removing pollutants through impingement, absorption, and accumulation (Manasa et al., 2023). They absorb gaseous pollutants through photosynthesis while simultaneously capturing particulate matter on their leaf surfaces, effectively reducing greenhouse gas levels in the atmosphere during the process. Although pollutants generate reactive oxygen species (ROS) that induce stress, plants produce ROS scavengers and detoxification agents to tolerate this damage (Escobedo et al., 2008). Leaves metabolize and assimilate pollutants into various tissues, acting as sinks that lower environmental contamination. Moreover, trees regulate microclimates through shading and transpiration, which reduce ambient temperatures, limit smog formation, and enhance pollutant dispersion (Paoletti et al., 2004).

Plant responses to air pollutants vary significantly based on their intrinsic tolerance capacity, which is influenced by a combination of internal traits and external environmental conditions. These intrinsic factors comprise physiological traits such as stomatal conductance, transpiration, and chlorophyll content; biochemical traits including antioxidant activity, ascorbic acid and proline; and morphological traits like leaf size, texture, and cuticle thickness. Seasonal variations further affect both the pollutant load and the physiological responses of plants.

The APTI quantifies a plant's ability to withstand toxic pollutants, calculated using four biochemical parameters: leaf extract pH, ascorbic acid content, total chlorophyll, and relative water content (Chauhan, 2010). Plants with higher APTI values exhibit greater tolerance and are suitable for pollution mitigation, while those with lower values are more sensitive and serve as bio-indicators of air quality (Chauhan and Joshi, 2008). Additionally, external leaf symptoms, *viz.* colour changes, shape alterations, necrotic patches, and stomatal characteristics are important indicators of a plant's response to pollution stress (Seyyednejad et al., 2011, Leghari et al., 2013).

In urban areas, dust from vehicular exhaust, unpaved roads, construction, and industries poses a significant problem. Trees play a vital role in mitigating this issue by effectively capturing dust. However, their dust retention capacity varies with height, canopy structure, phyllotaxy, and leaf morphological traits including size, pubescence, surface roughness, and presence of wax layer (Chauhan and Sanjeev 2008, Singh et al., 2002). Therefore, selecting tree species for green belts and avenue plantation should carefully consider both their pollution tolerance and dust retention abilities to maximize air quality improvement.

Bhubaneswar stands as one of the fastest-expanding smart cities in eastern India, characterized by rapid infrastructure development, burgeoning small to medium-scale industries, enhanced street transport networks, and a significant surge in vehicular traffic concurrent with its growing population. These developments have collectively contributed to the emission of substantial quantities of toxic pollutants, adversely impacting the city's air quality. Despite this, Bhubaneswar remains one of the few planned urban centers in the country where residents exhibit a strong commitment to environmental stewardship, with trees and green spaces deeply embedded in the city's cultural and social fabric. Among various avenue tree species observed along streets of the city, *Ficus religiosa*, *Polyalthia longifolia*, *Syzygium cumini,* and *Lagerstroemia speciosa* were very common because of their aesthetic morphological traits (Satapathy and Das 2021) and tolerance to cyclonic damages (Bhola and Sinha 2006). Understanding these variations is essential for selecting the most resilient and pollution-tolerant tree species can be effectively used in urban greening strategies to enhance air quality throughout the year.

MATERIAL AND METHODS

To assess the pollution tolerance of selected avenue tree species, three distinct zones were identified in Bhubaneswar. These included: Site 1 – the Mancheswar Industrial Area (MIA), Site 2 – the high-traffic corridor along National Highway 16 from Rasulgarh to Patrapara (NHTZ), and Site 3 – the Natural Forest area within the City Forest Division (NFCFD). Four common avenue tree species found in each zone (*Ficus religiosa*, *Polyalthia longifolia*, *Syzygium cumini*, and *Lagerstroemia speciosa*) were selected . These site, has a tropical savannah climate with a mean annual rainfall of 1,498 mm and an average temperature of 27.4 °C. Three distinguishable seasons, summer (March-June), rainy (July-October), and winter (November-February) can be observed. The pedogenic mass primarily consists of red laterite and alluvial soils. The morphometric characteristics and location details of the studied trees are provided in Table 1. To study the APTI of tree species, 15 plants of each species were randomly selected within the study area. From each plant, five leaf samples (each consisting of 4-6 fully developed leaves) were collected at an accessible height during the morning hours, between 7:00 and 8:00 a.m.

Biochemical analysis of leaf samples: The freshly collected leaf samples were analyzed for leaf extract pH, relative water content, total chlorophyll content, and ascorbic acid using standard procedures. The pH was determined using a pH meter (Systronics Model 361) following the protocol of Kaur and Nagpal (2017). The leaf relative water content (LRWC) was estimated according to the method described by Liu and Ding (2008). The concentrations of total chlorophyll pigments were estimated using Arnon's 80% acetone method (Arnon 1949). Ascorbic acid content was estimated colorimetrically using 3% metaphosphoric acid for extraction and 2,6-dichlorophenol-indophenol as the indicator dye, following the protocols of Ranganna (1977) and Sadasivam and Manickam (1992).

Estimation of air pollution tolerance index: The air pollution tolerance index (APTI) was calculated based on the concentrations of ascorbic acid (mg g^{-1}), total chlorophyll (mg g^{-1}), leaf extract pH, and relative water content (%) of leaf samples following the equation proposed by Singh and Rao (1983).

$$APTI = [Aa \times (Tcc + P) + R]/10$$

Table 1. Location coordinates and characteristics of selected plants at study site

Tree name	Leaf shape	Average height (m)	Average GBH* (cm)	Site 1 (MIA)	Site 2 (NHTZ)	Site3 (NFCFD)
FR	Cordate	30.25±5.0	115.25±8.7	20º30'78.1"N 85º84'60.5"E	20º23'18.2"N 85º74'75.4"E	20º34'87.5"N 85º66'18.4"E
PL	Lanceolate	18.70±6.2	75.81±4.5	20º30'78.5"N 85º84'60.8"E	20º23'17.6"N 85º74'75.9"E	20º34'87.8"N 85º66'18.9"E
SC	Elliptic-oblong and ovate	27.52±4.0	85.90±2.9	20º30'78.4"N 85º84'60.7"E	20º23'16.9"N 85º74'74.7"E	20º34'86.7"N 85º66'18.1"E
LS	Oval to elliptic	20.64±2.4	80.33±2.6	20º30'77.6"N 85º84'61.3"E	20º23'18.9"N 85º74'75.3"E	20º34'87.1"N 85º66'18.6"E

Tree species FR- *Ficus religiosa* L., PL- *Polyalthia longifolia* (Sonn.) Thwaites, SC- *Syzygium cumini* (L.) Skeels, and LS- *Lagerstroemia speciosa* (L.) Pers; sites: S1-Mancheswar industrial area (MIA), site2-Rasulgarh to Patrapara national highway (number 16) traffic zones including bus stand (NHTZ), and site3- natural forests in city forest division (NFCFD); GBH: girth at breast height (1.37 m from ground)

Where Aa represents the ascorbic acid content (mg g^{-1}) of the leaf sample, Tcc is the total chlorophyll content (mg g^{-1}), P denotes the pH of the leaf extract, and R is the relative water content (%) of the leaf. After obtaining the APTI values, tree species were classified into different categories based on their tolerance levels as: very sensitive (APTI < 1), sensitive (APTI 1 to 16), intermediate/moderately tolerant (APTI 17 to 29) and tolerant (APTI 30 to 100) (Kaur and Nagpal 2017).

Statistical analysis: To evaluate the spatial and temporal variations in the air pollution tolerance index (APTI) of the selected tree species, the significance of differences was tested at 5% level ($P < 0.05$) and the critical difference (CD) was calculated for pairwise comparisons. All calculations were performed using MS Excel 2011 and IBM SPSS 2020 package.

RESULTS AND DISCUSSION

Leaf extract pH: Leaf extract pH varied significantly with species, site, and season. Significant interactions were for species × site, and species × season (Table 2). The pH ranged from 3.72 (at traffic zone in *Lagerstroemia speciosa) to* 7.23 (at traffic zone in *Ficus religiosa*), peaking at 7.83 during the rainy season in the natural forest area, with overall means ranging from 3.72 to 7.61. *Polyalthia longifolia* and *Syzygium cumini* showed moderate pH ranges, from 5.01 (summer season, industrial area) to 6.53 (rainy season, natural forest area), and from 4.38 (summer season, traffic zone) to 6.40 (rainy season, natural forest area), respectively. *Lagerstroemia speciosa* had the most acidic values, with a low of 3.44 during the winter season in the industrial area and a high of 5.00 in the rainy season at the natural forest site, with overall means ranging from 3.72 to 4.38. Based on overall leaf extract pH values, the species were ranked as: *Ficus religiosa* > *Polyalthia longifolia* > *Syzygium cumini* > *Lagerstroemia speciosa*. These trends reflect the combined influence of inherent genetic traits and environmental stressors, particularly pollutants. The lower pH values observed in industrial and traffic zones can be attributed to higher concentrations of sulfur oxides (SOx), nitrogen oxides (NOx), and volatile organic compounds (Swami et al., 2004, Singare and Talpade 2013). Conversely, the higher pH levels recorded during the rainy season are likely due to the washing off and dilution of acidic particulate pollutants by rainfall (Das and Prasad, 2010, Dash and Sahoo, 2017).

Leaf total chlorophyll contents (TCC): The TCC of different trees exhibited significant variations with respect to species, site, and season . Significant interactions were also noted for species × site and species × season, while the interactions between season × site and species × season × site were not significant (Table 3). The total chlorophyll content ranged from lowest 2.82 mg g^{-1} in *L. speciosa* (traffic zone) to 7.83 mg g^{-1} in *F. religiosa (natural forest area)*. Based on overall total chlorophyll content values species were grouped in the order: *Ficus religiosa* > *Syzygium cumini* > *Polyalthia longifolia* > *Lagerstroemia speciosa*. Spatial variation also revealed significant differences. Trees growing in the natural forest area recorded the highest chlorophyll content, followed by those in the industrial area, with the lowest values in traffic zones. Jyoti and Jaya (2010) and Mir et al. (2008) also observed reduced chlorophyll levels in urban plants due to higher concentrations of automobile emissions and dust load from construction activities. The seasonal variation in total leaf chlorophyll content among selected tree species exhibited a consistent pattern, with peak values during the rainy season, a decline in winter, and subsequent increase in summer. The reduction in chlorophyll content during winter can be attributed to lower temperatures and reduced photoperiod, which limit enzymatic activity and photosynthesis, subsequently affecting chlorophyll

Table 2. Seasonal and spatial variations in leaf extract pH of tree species in Bhubaneswar

Species	Season and location											
	Rainy			Winter			Summer			Overall mean		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
FR	7.55	6.79	7.83	7.28	6.66	7.60	6.87	6.51	7.38	7.23	6.65	7.61
PL	5.67	5.27	6.53	5.91	5.99	6.04	5.01	5.59	6.09	5.53	5.61	6.22
SC	5.31	5.30	6.40	5.19	5.46	6.09	4.64	4.38	5.12	5.05	5.05	5.87
LS	4.21	4.34	5.00	3.44	3.52	4.25	3.52	3.59	3.90	3.72	3.82	4.38
C D (p=0.05)												
Species				0.30	Site			0.26	Seasons			0.26
Species × Site				0.52	Species × Seasons			0.52	Seasons × Site			NS
Species × Seasons × Site				NS								

biosynthesis (Jyoti and Jaya 2010). Additionally, increased dust deposition during winter has been shown to correlate negatively with chlorophyll content, further contributing to the decline (Singh et al., 2008). The rainy season supports optimal chlorophyll accumulation owing to adequate water availability, nutrient uptake, and favourable temperatures, whereas the moderate recovery in summer may be attributed to longer daylight hours despite heat and water stress. Sharma et al. (2017) also observed similar seasonal patterns in chlorophyll content in tree species exposed to urban particulate pollution. Significant interactions were noted between species × site and species × season. These variations may be attributed to the species' differential tolerance to air pollutants.

Relative water content of leaf (LRWC): Spatial and seasonal variations in LRWC among four tree species in Bhubaneswar showed significant differences influenced by species, season, and site (Table 4). *Ficus religiosa* consistently maintained high RWC (68.37% to 74.38%), indicating strong drought tolerance, while *Lagerstroemia speciosa* had the lowest values (41.15 to 51.71%), reflecting higher sensitivity to stress. LRWC was highest during the rainy season (75.60% in *P. longifolia* at the traffic zone) and declined through winter and summer seasons likely, due to reduced soil moisture and increased evapotranspiration. Natural forest sites generally supported better LRWC, likely due to lower pollution and better soil conditions, consistent with the observations of Joshi and Swami (2007). Significant interactions were also observed for the species × site and species × season, while the three-way interaction was insignificant.

Leaf ascorbic acid content (LAA): Spatial and seasonal variations in leaf ascorbic acid (LAA) content of the four tree species were observed, and the differences were significantly influenced by species, season, and site. Significant interactions were also noted for species × site and species × season, while the interactions between season × site and species × season × site were not significant (Table 5). Generally, LAA accumulation is often used as a physiological marker for oxidative stress resistance and pollution tolerance in plants (Khan et al., 2011). Among all species, *Polyalthia longifolia* demonstrated the highest

Table 3. Spatial and temporal variations in leaf chlorophyll content (mg g^{-1}) of trees in Bhubaneswar

Species	Season and location											
	Rainy			Winter			Summer			Overall mean		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
FR	7.89	6.10	8.18	6.61	4.51	7.53	7.28	5.30	7.78	7.26	5.31	7.83
PL	5.88	4.78	7.18	4.32	3.07	5.26	3.58	3.27	6.16	4.59	3.71	6.20
SC	7.04	5.48	8.39	4.66	3.67	6.16	6.30	4.23	6.91	6.00	4.46	7.15
LS	4.65	3.70	5.58	2.26	2.04	3.22	3.45	2.71	4.30	3.45	2.82	4.37
C D (p=0.05)												
Species				0.22	Site			0.19	Seasons			0.19
Species × Site				0.38	Species × Seasons			0.38	Seasons × Site			NS
Species × Seasons × Site				NS								

Table 4. Spatial and temporal variations in leaf relative water content (%) of trees in Bhubaneswar

Species	Season and location											
	Rainy			Winter			Summer			Overall mean		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
FR	73.38	74.38	71.71	71.97	73.40	69.80	69.70	71.49	68.37	71.68	73.09	69.96
PL	74.60	75.60	73.2	71.42	74.13	72.35	69.8	72.0	47.22	71.95	73.91	64.20
SC	50.42	54.09	49.84	49.02	55.82	47.22	47.99	48.97	45.56	49.14	52.96	47.54
LS	46.38	51.71	45.3	43.37	49.12	44.26	41.8	41.1	41.33	43.87	47.3	43.6
C D (p=0.05)												
Species				1.29	Site			1.12	Seasons			1.12
Species × Site				2.24	Species × Seasons			2.24	Seasons × Site			NS
Species × Seasons × Site				NS								

overall LAA content, with its maximum accumulation during winter season at site 2 (25.71 mg g^{-1}), which is a zone of high vehicular emissions. This trend implies that *P. longifolia* possesses a robust antioxidative defence mechanism capable of countering air pollution-induced oxidative stress, especially in colder months when pollution levels are high due to atmospheric inversion. Conversely, *Lagerstroemia speciosa* recorded the lowest LAA values across all sites and seasons, with the lowest mean (4.38 mg g^{-1}) observed in the summer at Site 3 (natural forest area), suggesting limited stress tolerance and metabolic responsiveness to environmental variations. It was also observed that the LAA content for most species was higher at traffic zones (site 2) compared to the relatively less polluted natural forest area (site 3), supporting the hypothesis that elevated pollution levels trigger enhanced antioxidant production in trees (Gill and Tuteja 2010). The findings are in line with the earlier reports of Mir et al. (2008), who pointed out that higher concentrations of automobile pollutants are one of the prime causes for the elevated level of leaf ascorbic acid content of plants grown along roads. Seasonal differences were also evident, with the winter season consistently showing elevated LAA concentrations, likely attributable to a combination of stress-induced higher antioxidant production and slower biochemical degradation processes under cooler climatic conditions.

Air pollution tolerance index (APTI): The significant difference in APTI was observed among species, sites, and seasons, along with significant interaction effects for species × site and species × season. *P. longifolia* consistently recorded the highest APTI across all sites and seasons, with a peak of 33.97 at Site 1 (MIA) during the rainy season. Its overall mean APTI across sites (30.50 at S1 and 31.48 at S2) classifies as tolerant (T) species. This high APTI score can be attributed to its efficient physiological and biochemical adaptations, such as higher chlorophyll content, stable pH, and robust ascorbic acid levels, which collectively enhance its resilience against oxidative stress induced by atmospheric pollutants. The ability to maintain relatively high APTI even in polluted environments makes it an ideal candidate for urban

Table 5. Spatial and temporal variations in leaf ascorbic acid content (mg g^{-1}) of trees

Species	Season and location											
	Rainy			Winter			Summer			Overall mean		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
FR	13.36	15.58	11.24	12.69	13.58	13.58	13.36	13.35	10.36	13.14	14.17	11.73
PL	20.85	23.71	15.36	20.18	25.71	16.71	19.51	22.38	8.60	20.18	23.94	13.56
SC	10.66	17.60	9.25	9.86	16.60	8.60	10.3	11.6	7.32	10.28	15.2	8.39
LS	7.38	7.48	6.49	6.38	6.48	5.48	5.38	5.48	4.38	6.38	6.48	5.45
C D (p=0.05)												
Species				0.53	Site			0.46	Seasons			0.46
Species × Site				0.92	Species × Seasons			0.92	Seasons × Site			NS
Species × Seasons × Site				NS								

Table 6. Spatial and temporal variations in air pollution tolerance index (APTI) of selected trees in Bhubaneswar

Species	Season and location												APTI class
	Rainy			Winter			Summer			Overall mean			
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	
FR	25.27	25.46	24.0	21.93	20.56	24.44	20.93	20.20	19.18	22.71	22.07	22.56	I
PL	33.97	33.04	30.2	28.46	32.19	27.63	29.06	29.20	12.74	30.50	31.48	23.53	T
SC	15.67	21.24	16.1	12.24	18.04	12.74	13.14	13.13	11.43	13.68	17.47	13.41	S
LS	12.61	11.78	12.7	11.17	10.63	11.01	9.35	8.07	9.28	11.04	10.16	11.00	S
C D (p=0.05)													
Species				0.62	Site			0.54	Seasons			0.54	
Species × Site				1.07	Species × Seasons			1.07	Seasons × Site			0.93	
Species × Seasons × Site				NS									

APTI class: I-intermediate/ moderately tolerant, S-sensitive and T-tolerant greening and pollution mitigation efforts (Bala et al., 2022). *Ficus religiosa*, categorized as intermediate or moderately tolerant (I), showed moderate APTI values with an overall mean ranging between 22.07 and 22.71, and a maximum of 25.46 at the highway traffic zone during the rainy season. These values suggest a reasonable level of pollution tolerance, although not as robust as *P. longifolia*. Its performance indicates some capacity to withstand environmental stress, likely due to moderate antioxidant responses and reasonable maintenance of leaf metabolic functions in polluted environments. The range of observed APTI value (22.07 to 25.46) of *F. religiosa* is well within the reported value of APTI 21.62 to 25.77 (Sharma et al., 2017). *Syzygium cumini* and *Lagerstroemia speciosa* were classified as sensitive (S) species, with low APTI values across all sites and seasons. *S. cumini* had a particularly low APTI during the summer at Site 3 (11.43), while *L. speciosa* displayed its lowest tolerance during the same season at Site 2 (8.07). These low scores imply poor biochemical buffering capacity under polluted conditions, possibly due to lower chlorophyll content, reduced leaf water retention, or less efficient antioxidant defence mechanisms. Their marked sensitivity suggests these species are less suited for plantation in urban or industrially affected zones, although they might still play a role in aesthetic landscaping in cleaner environments. Seasonal variation in APTI was also evident. Most species recorded higher APTI values during the rainy and winter seasons compared to summer (Fig. 1). This trend may be attributed to seasonal changes in ambient pollutant concentrations, plant physiological responses, and

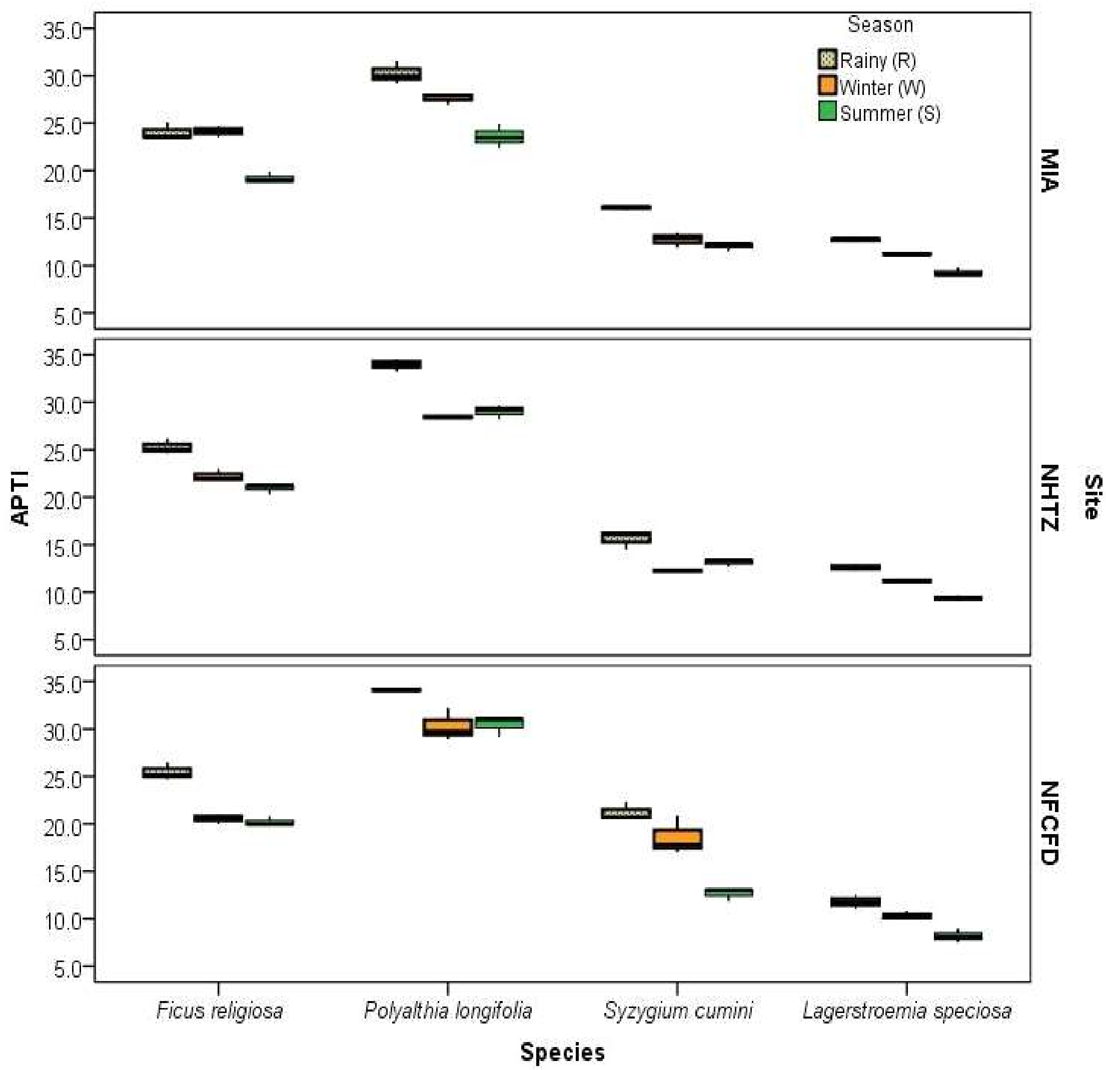

Fig. 1. Seasonal variations in air pollution tolerance index (APTI) of four tree species in different sites (MIA- Mancheswar industrial area, NHTZ- Rasulgarh to Patrapara national highway traffic zones, and NFCFD- natural forests in city forest division) of Bhubaneswar

Table 7. Pearson's correlation between leaf biochemical parameters and air pollution tolerance index (APTI)

Parameters	Leaf pH	TCC	LRWC	LAA
Total chlorophyll content (TCC)	0.760**			
Relative water content (LRWC)	-0.102	-0.405		
Ascorbic acid content (LAA)	-0.492	-0.695*	0.904**	
APTI	0.095	-0.046	0.915**	0.741**

* Correlation is significant at P<0.05
**Correlation is significant at P< 0.01

meteorological conditions. The rainy season, with its higher humidity and frequent precipitation, likely dilutes pollutant concentration, leading to reduced stress levels. In contrast, the summer season, characterized by elevated temperatures and drier conditions, exacerbates plant stress and reduces tolerance levels (Tripathy and Neema 2023).

Correlation between leaf biochemical parameters and APTI: The correlation between leaf relative water content (LRWC) and APTI was positive and significant indicating that tree species with higher water retention capacity exhibit greater tolerance to air pollution (Table 7). This emphasises the role of cell turgidity in maintaining cellular functions and mitigating the detrimental effects of pollutants. Similarly, leaf ascorbic acid (LAA) showed a strong positive correlation with APTI) suggesting that elevated levels of ascorbic acid enhance the plant's defence mechanisms against oxidative stress induced by air pollutants. Positive correlations between APTI and both LAA and LRWC content in various plant species were reported by Kour and Adak (2024). In contrast, total chlorophyll content (TCC) and leaf pH exhibited weak and non-significant correlations with APTI, implying that chlorophyll content and leaf pH are not directly associated with a plant's pollution tolerance. However, TCC showed a significant positive correlation with leaf pH, suggesting that a more alkaline leaf environment may stabilize chlorophyll molecules, thereby supporting photosynthetic activity. The strong correlation between LRWC and LAA infers that sufficient leaf turgidity enhances the synthesis and accumulation of antioxidants, thereby protecting plants from pollution-induced damage (Mehmood et al., 2024).

CONCLUSION

The study revealed significant spatial and seasonal variations in the air pollution tolerance index (APTI) among selected tree species in Bhubaneswar. *Polyalthia longifolia* exhibited the highest tolerance, suggesting its strong potential for urban area afforestation and pollution mitigation. *Ficus religiosa* showed moderate tolerance, while *Syzygium cumini* and *Lagerstroemia speciosa* were identified as sensitive species, more suitable for less polluted environments. Seasonal trends revealed higher APTI values during the rainy and winter seasons, likely due to favourable meteorological conditions. Higher leaf relative water content and ascorbic acid levels significantly enhance plant tolerance to air pollution, while chlorophyll content and leaf pH have an indirect association with tolerance. These findings highlight the importance of APTI-based species selection in urban plantation programmes aimed at enhancing environmental resilience and air quality.

REFERENCES

Arnon DI 1949. Copper enzyme in isolated chloroplasts, poly phenoloxidase in *Beta vulgaris*. *Plant Physiology* **24**(1): 1-15.

Bala N, Pakade YB and Katnoria JK 2022. Assessment of air pollution tolerance index and anticipated performance index of a few local plant species available at the roadside for mitigation of air pollution and green belt development. *Air Quality, Atmosphere and Health* **15**(12): 2269-2281.

Bhola N and Sinha SK 2006. Effect of super cyclone on different tree species in and around Bhubaneswar. *Indian Journal of Forestry* **29**(1): 25-30.

Chauhan A 2010. Tree as bio indicator of automobile pollution in Dehradun city: A case study. *Journal of New York Science* **3**(6): 88-95.

Chauhan A and Joshi PC 2008. Air quality index and its variations in Haridwar. *Journal of Environment and Bioscience* **22**(2): 171-176.

Chauhan A and Sanjeev 2008. Impact of dust pollution on photosynthetic pigments of some selected trees grown at nearby of stone-crushers. *Environment Conservation Journal* **9**(3): 11-13.

Das S and 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): 978-988.

Dash S and Sahoo S 2017. Air pollution tolerance index (APTI) of selected plants near bhusan sponge iron industry located in Rengali block of Sambalpur district, Odisha. *International Journal of Advanced Research* **5**(11): 599-607.

Escobedo FJ, Wagner DJ, Nowak CL, Maza DL, Rodrigyez M and Crane DE 2008. Analyzing the cost effectiveness of Santigo, Chiles policy of urban forests to improve air quality. *Journal of Environmental Biology* **29**: 377-379

Gill SS and Tuteja N 2010. Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. *Plant physiology and biochemistry* **48**(12): 909-930.

Joshi PC and Swami A 2007. Physiological responses of some tree species under road side automobile pollution stress around city of Haridwar. *Indian Environmentalist* **27**: 365-374.

Kaur M and Nagpal AK 2017. Evaluation of air pollution tolerance index and anticipated performance index of plants and their application in development of green space along the urban areas. *Environmental science and pollution research* **24**: 18881-18895.

Khan T, Mazid M and Mohammad F 2011. A review of ascorbic acid potentialities against oxidative stress induced in plants. *Journal of agrobiology* **28**(2): 97-111.

Kour N and Adak P 2024. Assessing the relationship between the biochemical and the morphological factors (leaf surface area and leaf surface texture) of industrial and roadside plants. *Environmental Monitoring and Assessment* **196**: 559.

Leghari SK, Zaid MA, Sarangzai AM, Faheem M, Shawani GR and Ali W 2013. Effect of roadside dust pollution on growth and total chlorophyll contents of *Vitis vinifera* L. (grape). *African Journal of Biotechnology* **13**(11): 1237-1242.

Liu YJ and Ding H 2008. Variation in air pollution tolerance index of plants near a steel factory: implication for landscape – plant species selection of industrial areas. 5th WSEAS *Int. Conf. on Environment, Ecosystems and Development, Tenerife, Spain*. **4**(1): 24-32.

Lohwasser J, Bolognesi T and Schaffer A 2025. Impacts of population, affluence and urbanization on local air pollution and land transformation: A regional STIRPAT analysis for German districts. *Ecological Economics*, **227**: 108416.

Manasa C, Salimath SK, Hegde R, Dechamma DN and Gooli M 2023. Roles of trees for abatement of environmental pollution: A review. *International Journal of Bio-resource and Stress Management*, **14**(10): 1403-1410.

Mehmood Z, Yang HH, Awan MUF, Ahmed U, Hasnain A, Luqman M, Muhammad S, Sardar AA, Chan T and Sharjeel A 2024. Effects of air pollution on morphological, biochemical, DNA, and tolerance ability of roadside plant species. *Sustainability* **16**(8): 3427.

Mir QA, Yazdani T, Kumar A, Narain K and Yunus M 2008. Vehicular pollution and pigment content of certain avenue trees. *Pollution Research* **27**: 59-63.

Paoletti E, Karnosky DF and Percy KE 2004. Urban trees and air pollution. *Forestry Serving Urbanised Societies* **14**: 129-154.

Ranganna S 1977. *Manual of analysis of fruit and vegetable products*. TaTa Mc Graw-Hil lPublishing Company Ltd. New Delhi. pp. 94-101.

Sadasivam S and Manickam A 1992. *Biochemical methods for Agricultural Sciences*. Eastern Ltd. p-178.

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Satapathy MK and Das SK 2021. Plant community analysis of Bhubaneswar smart city, Odisha, India. *Indian Journal of Ecology* **48**(1): 147-153.

Seyyednejad SM, Majdian K, Koochak H and Nikneland M 2011. Air pollution Tolerance Indices of some plants around Industrial Zone in South of Iran. Asian J Biol Sci **4**(3): 300-305.

Shaheen A, Sheng J, Arshad S, Muhammad H and Salam S 2025. Forecasting the determinants of environmental degradation: a gray modeling approach. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, **47**(1): 1084-1104.

Sharma B, Sharma S, Bhardwaj SK, Kaur L and Sharma A 2017. Evaluation of Air Pollution Tolerance Index (APTI) as a tool to monitor pollution and green belt development: A review. *Journal of Applied and Natural Science* **9**(3): 1637-1643.

Singare PU and Talpade MS 2013. Physiological responses of some plant species as a bio-indicator of roadside automobile pollution stress using the air pollution tolerance index approach. *International Journal of Plant Research* **3**(2): 9-16.

Singh RB, Das UC, Prasad BB and Jha SK 2002. Monitoring of dust pollution by leaves, *Pollution Research* **21**: 13-16.

Singh SK and Rao DN 1983. Evaluation of the plants for their tolerance to air pollution, pp. 218-224. **In**: Proceedings: *Symposium on Air Pollution control* **1**(1), IIT Delhi.

Swami A, Bhatt D and Joshi PC 2004. Effects of automobile pollution on sal (*Shorea robusta*) and rohini (*Mallotus phillipinensis*) at Asarori, Dehradun. *Himalayan Journal of Environment and Zoology* **18**(1): 57-61.

Tripathi DP and Neema AK 2023. Seasonal variation of biochemical parameters and air pollution tolerance index (APTI) of selected plant species in Delhi city, and detailed meta-analysis from Indian metropolitan cities. *Atmospheric Environment* **309**: 119862.