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Evaluation of tree species using Air Pollution Tolerance Index for urban landscaping in Delhi

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ABSTRACT

Air pollution which negatively impacts both human health and the environment is a mountainous challenge before policymakers and city planners in urban areas. Urban landscaping with effective pollution-combating tree species is one of the soundest strategies to mitigate pollution adversaries. However, not all tree species are equally suitable for urban environments due to varying levels of tolerance to air pollution. This study has been designed to evaluate the physiological and biochemical responses of seven commonly occurring tree species in the Talkatora garden (TG) and Income Tax Office (ITO) representing non-polluted and polluted locations in Delhi, respectively applying Air Pollution Tolerance Index (APTI). The current research study was carried out during 2021–22 at the Division of Floriculture and Landscaping, ICAR-Indian Agricultural Research Institute, New Delhi. In tree species understudy, it was recorded that the *p*H of leaf extract, total chlorophyll, and relative water content was lower in the winter season than summer season except for the ascorbic acid. *Ficus religiosa* with the highest APTI value (23.23) followed by *Pongamia pinnata* (20.85) were found most tolerant tree species to air pollution in Delhi during the winter season at the polluted (ITO) and non-polluted (TG) location respectively with a reverse trend for the summer season. *Polyalthia longifolia* was found most sensitive (bioindicator plant) to air pollution among the seven trees under study owing to the lowest APTI values (11.14 and 12.58) across the seasons at non-polluted (TG) and polluted (ITO) locations respectively. Furthermore, *Ficus religiosa* with the highest APTI across the locations and seasons was assessed as the best performer, hence, could be the most efficient option for landscaping in polluted and non-polluted areas.

Keywords: APTI, Delhi, Landscape, Urban green space

Urbanization led to exponential growth in the number of vehicles, thermal power plants and factories, along with other anthropogenic activities in Delhi has contributed significantly to rendering its air quality bad to worse (Sharma *et al.* 2018). The coal-based thermal power plants in the vicinity of Delhi emit pollutants such as sulphur dioxide (SO_2), nitrous oxide (NO_2), and particulate matter (PMs) in amounts detrimental to air quality. These power plants are a significant source of air pollution, contributing to the overall pollution levels in the city (Parveen *et al.* 2021). The smog and pollutants released during biomass burning contribute to a great extent to the formation of PM and hazardous gases (Chaudhary *et al.* 2019, Beeralainni and Patil 2023).

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Grasses also play a vital role in managing air pollution as their dense root system helps stabilize soil, preventing erosion, while the plant absorbs pollutants from the air having the ability to sequester carbon and reduce particulate matter contributes to overall environmental health (Hoodaji *et al.* 2022). The leaves' intricate structures, including hairs and microscopic pores, help capture and retain particulate matter, reducing the presence of pollutants in the air (Gerstenberg *et al.* 2016, Zhao *et al.* 2017). However, the degree to tolerate a particular level of air pollution greatly varies with the type of species and their adaptability. The indices that assess the tolerance of tree species to air pollution depend on various physiological and biochemical parameters, for example, leaf chlorophyll content, leaf relative water content, leaf extract *p*H, and ascorbic acid content and thereby aid in the selection of tree species for urban landscaping is Air Pollution Tolerance Index (APTI).

The study aimed to aid in the decision-making for advising the appropriate tree species tolerant to air pollution concerning Delhi's pollution levels under the recently observed highest levels of air pollution. The outcomes will provide a ready-made solution to urban landscaping professionals, urban city planners, horticulturists and township architects.

MATERIALS AND METHODS

The present study was carried out during summer and winter seasons of during 2021–22 at ICAR-Indian Agricultural Research Institute, New Delhi. Two locations in New Delhi were taken into consideration based on the nearby activities concerning air pollution to carry out the present study. One of the study locations, Talkatora Garden (Non-polluted) is a park with substantial green spaces and a variety of tree species while the Income Tax Office (I.T.O.) (Polluted) represents areas with considerable traffic and other pollution-inducing industries.

Sample collection of tree species: Twenty completely developed leaves from seven different tree species were collected as samples for biochemical analysis between the hours of 6–8 a.m. in the morning. Samples were kept at 4°C temperature and the fresh weight of the leaves (20–25 nos) was instantly measured with a digital weighing machine. A composite leaf sample was taken from each tree species for further investigation.

Biochemical arameter analysis of leaf samples

Leaf extract p*H:* A fresh sample of recently developed leaves weighing 0.5 g was centrifuged using distilled water to measure the leaf extract *p*H using a digital *p*H meter (Model: ESICO1013) calibrated with a buffer solution of *p*H 4.0 and 9.0 (Bandara and Dissanayake 2021).

Total chlorophyll content: The leaf total chlorophyll content of tree species under investigation was measured using the method described by Arnon (1949).

Reagents: Dimethyl sulphoxide (DMSO):

Procedure: 0.1 g of leaf samples were placed in a vial containing 5 ml of DMSO. Vials were then kept in the boiling water bath at 50ºC for 30 min. Absorbance was recorded at 645 nm and 663 nm by using a UV 2600 spectrophotometer. The following Arnon's equations were used to calculate the chlorophyll content:

$$\text{Total chlorophyll content (mg/g)} = 20.2\ (A645) + 8.02\ (A665) \times V/1000 \times W$$

where, A, Absorbance of particular wavelengths; V, Final volume of chlorophyll extract in 80% acetone; W, Weight of the fresh tissue extracted.

Ascorbic Acid: The formation of a pink-coloured complex in an acidic solution as a result of ascorbic acid's reduction of dinitro phenyl hydrazine to phenyl hydrazone serves as the basis for ascorbic acid measurement (Mukherjee Choudhuri 1983).

Estimation: 0.1 ml of aliquot (supernatant) in the test tube was taken for estimation. To this added 0.5 ml of DNPH reagent and 2 drops of 10% thiourea. Incubated the test tubes at 50°C for 30 min. Then 2.5 ml of 80% sulphuric acid was added and on cooling the absorbance at 540 nm was read. The concentration of ascorbic acid was calculated using standard value (0.04 mg= 0.826 OD).

Relative water content of leaf (RWC): The approach suggested by Liu and Ding (2008) was used to estimate the relative water content of the leaf samples as:

$$\text{TWC (\%)} = \frac{FW - DW}{TW - DW} \times 100$$

where, FW, Fresh Weight (g); DW, Dry Weight (g); TW, Turgid Weight (g).

Air Pollution Tolerance Index (APTI): Ascorbic acid, total chlorophyll, leaf extract *p*H, and RWC were taken into account for estimating the APTI. The APTI was calculated with the following equation provided by Singh and Rao (1983):

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

where, A, Ascorbic acid (mg/g); T, Total chlorophyll (mg/g); P, *p*H of Leaf extract, and R, Relative water content (%).

Statistical inference: A linear regression analysis between the independent variables relative water content, ascorbic acid, leaf extract *p*H, total chlorophyll content, and the dependent variable APTI was performed with the XL STAT (version 10) program. The scatter plots illustrate the degree of correlation (R^2) between the variables recorded across two locations and seasons.

RESULTS AND DISCUSSION

Biochemical parameters: All the biochemical parameters of tree species under study were found to vary significantly due to different locations and seasons (Tables 1 and 2). In the summer season, the highest RWC (88.23% and 86.47%) was observed in *F. religiosa* in the non-polluted (TG) and polluted location (ITO), respectively whereas *F. infectoria* registered a maximum RWC (%) of 94.95% and 92.56% in non-polluted (TG) and polluted (ITO) locations in winter season, respectively. The lowest RWC 72.52% was recorded in *P. longifolia* in the polluted location (ITO) in the summer season. Karmakar *et al.* (2021) and Sumangala *et al.* (2018) also emphasized that there is a higher percentage of RWC in plants under stress conditions which increases the resistance in the plants to withstand and is more tolerant to oxidative stress due to air pollution.

Across all seven tree species, the highest leaf extract *p*H values of 7.95 and 7.85 were found in *F. religiosa* in the summer and winter seasons, respectively in the non-polluted area (TG). However, in the polluted location (ITO) leaf extract of the same species registered a *p*H of 7.56 in the summer season whereas, in the winter season, registered 7.55 highest leaf extract *p*H. On the other hand, the lowest *p*H was observed in *P. pinnata* 6.12 in polluted location (ITO) in the summer season. Differences in leaf extract *p*H might be a result of the effect of air pollution on the sensitivity of stomata. Consequently, leaves, with the lowest *p*H values are highly affected by air pollutants, while those with maximum *p*H are a high degree tolerant to pollutants (Sen *et al.* 2017). Similar studies suggested that plants with low *p*H of leaf extracts are more prone to air contamination, while those with pH around 7 or more are more tolerant (Shakeel *et al.* 2022).

In general, the total chlorophyll content irrespective of location was found higher in the summer season than in the winter season. *A. scholaris* with 3.02 mg/g total chlorophyll content registered the highest among all the seven tree species under study during the summer season, whereas, in the winter season it was found highest in *P. pinnata* (2.95 and 2.50 mg/g) at both non-polluted (TG) and polluted location, respectively. However, at the polluted location (ITO) *F. religiosa* (2.78 mg/g) registered the highest chlorophyll content in the summer season. Contrarily, the lowest total chlorophyll content at the polluted location (ITO) in the winter season was also observed in *F. religiosa* (1.65 mg/g). Chloroplast efficiency becomes reduced by air pollution; hence, the rate of photosynthesis and the conductance of stomata are affected. Consequently, the leaves' total chlorophyll content is observed lowest (Dash *et al.* 2018, Gupta *et al.* 2020). Higher levels of chlorophyll content in tree species at the polluted site as a mechanism to favour tolerance to pollutants were also reported by Ogunkunle *et al.* (2015).

A wide variation in antioxidant activity in terms of ascorbic acid content has been recorded across the seasons and locations. In general, the ascorbic acid content was found higher in the winter season in all the tree species, except *A. scholaris* at both locations, *F. religiosa* at the non-polluted location, and *C. fistula* at the polluted location which experienced a dip in antioxidant activity in the winter season. In the summer season, *P. pinnata* synthesized the highest ascorbic acid content (11.96 and 14.28 mg/g) in non-polluted (TG) and polluted locations (ITO), respectively. *F. religiosa* and *P. pinnata* registered the highest ascorbic acid 10.15 and 16.52 mg/g in non-polluted (TG) and polluted locations (ITO) in the winter season respectively. In the summer season, the lowest ascorbic acid 11.96 mg/g was observed in *P. longifolia* at the non-polluted location (TG). Leaves collected from polluted location reported higher levels of ascorbic acid content which depicted the tolerance level of tree species against the pollution-prone environment (Kaur and Nagpal 2017, Sharma *et al.* 2022).

Air Pollution Tolerance Index (APTI): The values of APTI calculated based on the content of biochemical parameters of each tree species under study were found to vary significantly across the locations and seasons. *F. religiosa* (20.33 and 20.28) recorded greater APTI values whereas *P. longifolia* was found lowest (11.14 and 12.58)

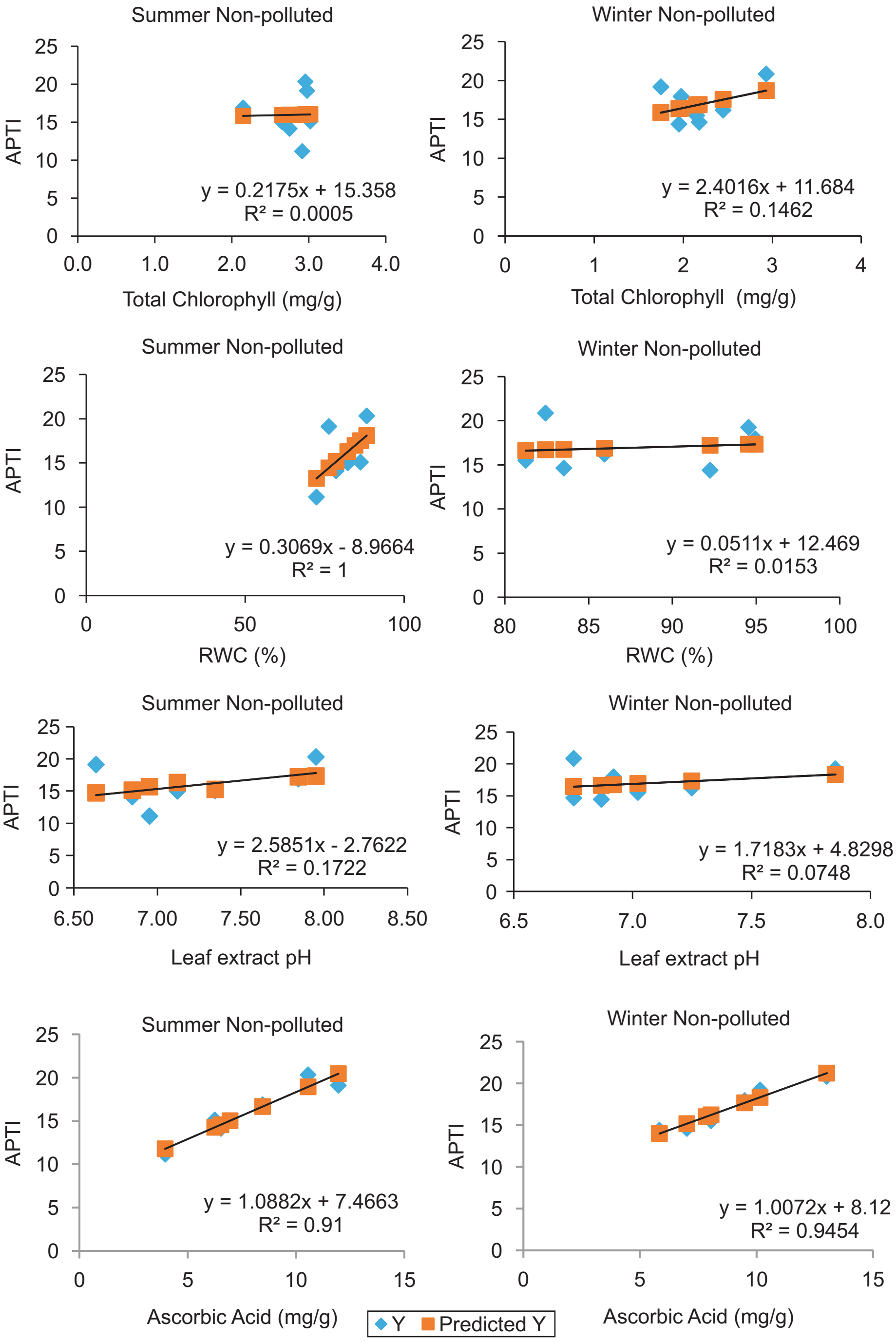

Fig. 1 Correlation analysis of APTI with biochemical parameters in non-polluted location (TG) during summer and winter seasons.

in polluted (ITO) and non-polluted location (TG) in the summer season, respectively. In the winter season, maximum APTI values were found in *F. religiosa* (23.23) and *P. pinnata* (20.85) in polluted locations (ITO) and non-polluted locations (TG), respectively whereas, the lowest APTI values were found in *A. scholaris* (14.38) and *A. indica* (14.01) in non-polluted locations (TG) and polluted locations (ITO) in the winter season. Trees that have greater APTI scores are more resistant to pollutants and hence ideal for planting in polluted locations (Maan *et al.* 2016). The plants with high APTI values are tolerant to air pollution and can be utilized as filters/sinks to mitigate air pollution while plants with low APTI can indicate the sensitive nature of plants which can be used as bio-indicators (Madan and Chauhan 2015, Bala *et al.* 2022).

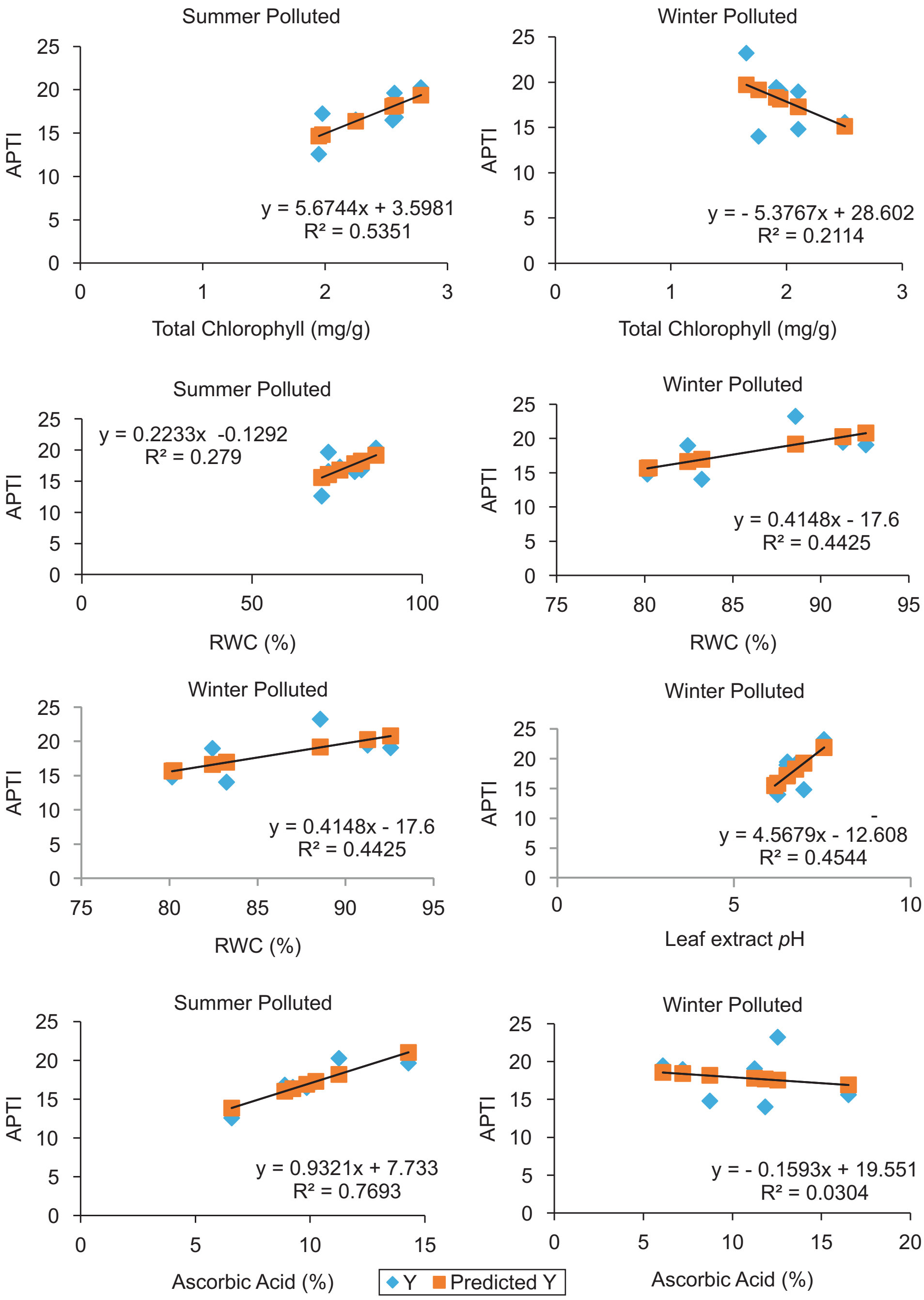

Fig. 2 Correlation analysis of APTI with biochemical parameters in polluted location (ITO) during summer and winter seasons.

Biochemical parameters and APTI correlation studies: The linear regression plots of total chlorophyll, RWC, leaf extract *p*H and ascorbic acid with APTI for the non-polluted location (TG) and polluted location (ITO) for the summer and winter seasons are shown in Fig. 1 and Fig. 2, respectively. APTI was found positively correlated with RWC, leaf extract *p*H and ascorbic acid in the non-polluted location (TG) for both seasons, while total chlorophyll was found to follow a slightly negative correlation with APTI during the summer season in the non-polluted location (TG). However, in the winter season correlation of APTI with total chlorophyll remained positive. The R^2 of total chlorophyll with APTI in non-polluted (TG) location for the summer and winter seasons was worked out at 0.0005 and 0.1462, respectively.

Similarly, R^2 of RWC vs. APTI in non-polluted location (TG) for the summer and winter seasons was estimated at 1 and 0.0153, respectively, while it was 0.1722 (summer) and 0.0748 (winter) for leaf extract *p*H. The R^2 of APTI vs. ascorbic acid in non-polluted location (TG) for the summer and winter seasons were recorded as 0.91 and 0.94, respectively (Fig. 1). Similarly, R^2 of total chlorophyll vs. APTI in polluted location (ITO) for the summer and winter seasons was 0.5351 and 0.2114, respectively, while it was 0.279 (summer) and 0.4425 (winter) for RWC. The R^2 of APTI vs. leaf extract *p*H in polluted location (ITO) for the summer and winter seasons were 0.076 and 0.4544, respectively (Fig. 2). Likewise, in polluted location (ITO), the R^2 of ascorbic acid with APTI during the summer and winter season was recorded 0.7693 and 0.0304, respectively. A similar trend in the relationship of APTI with biochemical parameters was also observed by Kaur and Nagpal (2017).

Table 1 Value of biochemical parameters with APTI of tree species under study at the non-polluted (TG) and polluted location (ITO) in the winter season

Tree species	Locations (non-polluted and polluted)	Relative water content (%)	Leaf extract *p*H	Total chlorophyll content (mg/g)	Ascorbic acid (mg/g)	APTI
Azadirachta indica	TG	85.95	7.25	2.45	7.85	16.21
	ITO	83.25	6.24	1.76	11.85	14.01
Alstonia scholaris	TG	92.25	6.87	1.95	5.85	14.38
	ITO	91.25	6.52	1.91	6.10	19.43
Ficus religiosa	TG	94.55	7.85	1.75	10.15	19.21
	ITO	88.56	7.55	1.65	12.55	23.23
Pongamia pinnata	TG	82.43	6.75	2.93	13.02	20.85
	ITO	80.25	6.15	2.50	16.52	15.58
Cassia fistula	TG	81.25	7.02	2.15	8.05	15.51
	ITO	80.15	6.98	2.10	8.74	14.80
Polyalthia longifolia	TG	83.52	6.75	2.18	7.02	14.63
	ITO	82.44	6.50	2.10	7.22	18.94
Ficus infectoria	TG	94.95	6.92	1.98	9.50	17.95
	ITO	92.56	6.75	1.95	11.25	19.05

APTI, Air Pollution Tolerance Index.

The results implied that ascorbic acid is the most significant factor while considering the plant's pollution tolerance potential at a given location.

The biochemical response to air pollution at the same degree of exposure and its derived indices worked out for all the seven tree species under study was found different owing to the degree of adoption, endurance, and ability to combat its adverse effects. The current study showed a sharp decrease in the relative water content of the leaf, leaf extract *p*H, and total chlorophyll content of the tree species under study in the polluted location. Hence, the tree species with higher APTI can be selected for the regions with higher pollution levels (ITO) in a bio-resistance based ecologically appropriate manner. Specifically, *F. religiosa, F. infectoria, A. scholaris* and *P. longifolia* are the native tree species found most efficient for combating air pollution throughout the seasons and can be recommended for landscape design and green space cover in Delhi and the NCR to balance the levels of air pollution. Moreover, tree species such as *Polyalthia longifolia* found sensitive to air pollution can be deployed

Table 2 Value of biochemical parameters with APTI of tree species under study at the non-polluted (TG) and polluted location (ITO) in the summer season

Tree species	Locations (non-polluted and polluted)	Relative water content (%)	Leaf extract *p*H	Total chlorophyll content (mg/g)	Ascorbic acid (mg/g)	APTI
Azadirachta indica	TG	82.25	7.12	2.65	6.95	15.02
	ITO	80.25	6.98	2.25	9.25	16.57
Alstonia scholaris	TG	86.25	7.35	3.02	6.25	15.11
	ITO	82.23	7.13	2.58	8.89	16.85
Ficus religiosa	TG	88.23	7.95	2.95	10.55	20.33
	ITO	86.47	7.56	2.78	11.25	20.28
Pongamia pinnata	TG	76.25	6.63	2.98	11.96	19.12
	ITO	72.46	6.12	2.57	14.28	19.66
Cassia fistula	TG	78.63	6.85	2.75	6.52	14.12
	ITO	71.52	6.85	2.55	9.86	16.53
Polyalthia longifolia	TG	72.36	6.95	2.91	3.95	11.14
	ITO	70.52	6.45	1.95	6.58	12.58
Ficus infectoria	TG	84.52	7.85	2.15	8.45	16.90
	ITO	75.86	7.45	1.98	10.25	17.26

APTI, Air Pollution Tolerance Index.

as an effective atmospheric pollutant indicator. Higher APTI value tree species are recommended to replace with existing low APTI value tree species which will help in reducing the air pollution severity in Delhi. The outcome of this study will be helpful for Delhi-based Horticultural Departments, town planners, and urban green space architects for future planning of landscape activities in Delhi. Therefore, these tree species can be recommended for landscaping designing and green space cover to enhance the long-term reduction of the atmospheric pollution practices in Delhi and NCR.

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