Evaluation of Air Pollution Tolerance Index (APTI) of selected tree species of industrial areas in Nasik City Maharashtra,India

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Abstract:
The Air Pollution Tolerance Index (APTI) of selected tree species in industrial areas of Nashik city was assessed to evaluate their tolerance to air pollution. The study focused on various plant species in the Satpur MIDC industrial zone of Nashik. Some plant species exhibit tolerance to air pollution, while others are susceptible. Susceptible species serve as bio-indicators of air pollution, whereas tolerant species can be utilized for green belt development. This study examined seasonal variations in APTI by analysing 13 commonly available tree species: *Terminalia catappa* L., *Mangifera indica* L., *Ficus religiosa* L., *Ficus benghalensis* L., *Azadirachta indica* A. Juss, *Monoon longifolium* (Sonn.) B. Xue & R. M. K. Saunders, *Senna siamea* (Lam.) H. S. Irwin & Barneby, *Delonix regia* (Bojer ex Hook.) Raf., *Dalbergia sissoo* Roxb. Ex DC, *Samanea saman* (Jacq.) Merr., *Pongamia pinnata* (L.) Pierre, *Eucalyptus tereticornis* Sm., and *Millingtonia hortensis* L. f., Key physicochemical parameters influencing APTI—total chlorophyll content, leaf extract pH, relative water content, and ascorbic acid—were recorded. These factors varied across three different seasons within the study period (July 2022 – August 2023). Among the analysed species, *Ficus benghalensis* exhibited the highest APTI value (14.01), indicating greater tolerance to air pollution, while *Eucalyptus tereticornis Sm.,* had the lowest APTI value (9.16), and suggesting higher susceptibility. The findings highlight the importance of selecting appropriate tree species for urban green belt planning to mitigate industrial air pollution.

Key Words: *Air pollution, Chlorophyll, Relative water content, Tolerance.*

INTRODUCTION:

Urban vegetation plays a crucial role in improving air quality and maintaining ecological balance in rapidly growing cities. As urbanization and industrialization continue to expand, air pollution has become a major environmental concern, adversely affecting both human health and plant life. Plants act as natural filters by absorbing pollutants, sequestering carbon dioxide, and releasing oxygen. However, they are also vulnerable to the harmful effects of air pollutants such as sulphur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter (PM), and ozone (O_3), which can alter their physiological and biochemical characteristics.

Among the various methods used to assess the impact of air pollution on plants, bio monitoring has emerged as a valuable tool. It involves evaluating the physiological responses of plants to pollution through the analysis of specific biochemical and physicochemical parameters. Leaves, being the most exposed parts of plants, show visible symptoms such as chlorosis, necrosis, and stomatal damage when subjected to high pollution levels. Additionally, biochemical changes such as fluctuations in chlorophyll content, variations in leaf extract pH, and alterations in.

One of the most widely used approaches to assess plant response to air pollution is the **Air Pollution Tolerance Index (APTI)**. The APTI is calculated using four key parameters:

- **Total chlorophyll content (TCC)** – Indicates the photosynthetic efficiency of plants and their ability to sustain metabolic activities under pollution stress.
- **Leaf extract pH** – Affects enzymatic activity and metabolic functions, reflecting the degree of pollution impact.
- **Relative water content (RWC)** – Represents the water retention capacity of plants, which is crucial for their survival under stress conditions.
- **Ascorbic acid content** – Acts as an antioxidant that helps plants neutralize oxidative stress caused by air pollutants.

Several studies have emphasized the significance of APTI in determining plant tolerance and sensitivity to air pollution. Researchers such as Agrawal and Tiwari (1997),{1} Dwivedi and Tripathi (2007) {2}, Liu and Ding (2008) {3}, and Dwivedi et al. (2008) {4} have contributed valuable insights into the selection of plant species for urban planning and environmental management. Plants with high APTI values are considered **tolerant species**, which can be effectively used for green belt development, while those with low APTI values serve as **bio-indicators** of air pollution. Identifying such species is essential for designing green belts that help mitigate air pollution and improve urban environmental quality.

In the present study, seasonal variations in physicochemical parameters were analysed to calculate the APTI of 13 commonly available plant species in the **Satpur Industrial Region of Nashik city, Maharashtra**. The study aims to assess their pollution tolerance and sensitivity, providing valuable insights for urban planners, landscape developers, and environmental policymakers to enhance urban greenery and mitigate the adverse effects of industrial air pollution. The APTI calculations were carried out following the method proposed by Singh et al. (1992),{5} allowing a comprehensive evaluation of plant responses to air pollution over different seasons.

By understanding the tolerance levels of different plant species, this study contributes to the effective selection of vegetation for air pollution control and sustainable urban development.

MATERIAL AND METHODOLOGY

Study Area:

Satpur MIDC Area Source: Maharashtra Industrial Development Corporation Website

Ambad MIDC Area:
Source: Maharashtra Inertial Development Corporation Website

The study was conducted in the Nashik Industrial Region, specifically in the Satpur MIDC area of Nashik city, Maharashtra. The study area is geographically located between 18.33° and 20.53° North latitude and 73.16° and 75.16° East longitude. This region experiences significant industrial activity, making it a suitable site for assessing the impact of air pollution on vegetation.{6}

Selection of Plant Species

A total of 13 commonly available plant species from the study area were selected for evaluation. The selected species are:

- *Terminalia catappa* L.
- *Mangifera indica* L.
- *Ficus religiosa* L.
- *Ficus benghalensis* L.
- *Azadirachta indica* A. Juss
- *Monoon longifolium* (Sonn.) B. Xue & R. M. K. Saunders
- *Senna siamea* (Lam.) H. S. Irwin & Barneby
- *Delonix regia* (Bojer ex Hook.) Raf.
- *Dalbergia sissoo* Roxb. ex DC
- *Samanea saman* (Jacq.) Merr.
- *Pongamia pinnata* (L.) Pierre
- *Eucalyptus tereticornis* Sm.
- *Millingtonia hortensis* L. f.

The study was conducted over a **one-year period from July 2022 to August 2023**, during which seasonal variations in plant responses were observed.

Sample Collection and Analysis

Mature leaves of the selected plant species were collected in polythene bags with utmost care to ensure samples were taken from isoecological conditions. The collected leaves were analysed for the following four key physicochemical parameters, which contribute to the calculation of the Air Pollution Tolerance Index (APTI):

1. **Total Chlorophyll Content**

1.0 g of the greenest leaves were selected and cleaned thoroughly with water and dried at room temperature for a while. Then samples were macerated in a pestle with mortar by adding

20–25 ml of 80% acetone. A pinch of magnesium carbonate was added to the material prior to extraction to prevent deterioration of chlorophyll. The leaf extract content was centrifuged at 2000 r. p. m. for 15 min in the cooling centrifuge. Transferred the extract to a volumetric flask and made to the volume of 50 ml using 80% acetone. The optical density of this green solution read at 645 nm (D645), and 663 nm (D663) using a spectrophotometer and the total chlorophyll calculated with the following formula by Arnon {7}. CT = 20.2 (D645) ± 8.02 (D663)

2. **Ascorbic Acid Content**

Ranganna, S. (1986) {8}. Manual of Analysis of Fruit and Vegetable Products. Tata McGraw- Hill. This book details methods for the estimation of ascorbic acid, including spectrophotometric techniques. Leaves are homogenized in a buffer solution (such as phosphate buffer) to extract ascorbic acid.

Reaction with Reagents: The extract is treated with DCPIP, which is reduced by ascorbic acid, causing a colour change from blue to colourless.
Spectrophotometric Measurement: The absorbance of the solution is measured at 515-520 nm, and the ascorbic acid concentration is determined by comparison with a standard calibration curve.

1. **Leaf Extract pH**

The digital pH meter was calibrated using standard buffer solutions at pH 4.0 and 7.0 before use. Leaf extract pH was measured following the homogenization of fresh leaf tissue in distilled water, as described by. Kakde, U. M. (2017) {9}.

2. **Relative Water Content (RWC)**

$$RWC = \left(\frac{FW - DW}{TW - DW}\right) \times 100$$

Where:
- *FW* = Fresh weight of leaves
- *TW* = Turgid weight of leaves (obtained after immersing leaves in water overnight)
- *DW* = Dry weight of leaves (determined after drying at 70°C in an oven)

Calculation of Air Pollution Tolerance Index (APTI):
The collected leaf samples were analysed for Total Chlorophyll Content (T), Ascorbic Acid Content (A), pH of Leaf Extract (P), and Relative Water Content (R). The Air Pollution Tolerance Index (APTI) was calculated using the formula given by Singh et al. (1991) {10}.

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

This formula integrates the physiological and biochemical parameters of plants to determine their tolerance or sensitivity to air pollution.

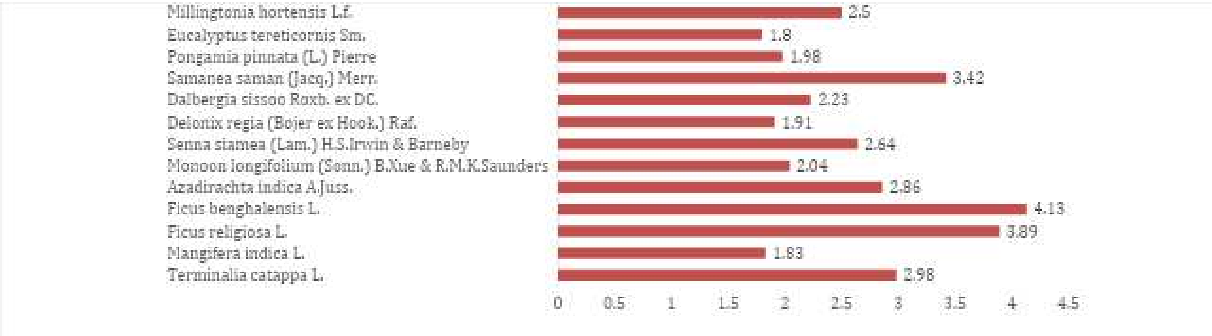
Table 1 shows Concentration of Chlorophyll content (mg/gm) of different tree species at Nasik MIDC Area, Nasik (August 2022 to July 2024)

S.N.	*Tree Species*	Aug.2022	Sep. 2022	Oct. 2022	Nov.2022	Dec. 2022	Jan. 2023	Feb. 2023	Mar 2023	Apr. 2023	May 2023	June. 2023	July 2023	Average
1	*Terminalia catappa* L.	4.24	4.31	4.12	4.02	3.98	3.75	3.71	3.66	3.65	3.78	3.84	3.89	3.91
2	*Mangifera indica* L.	3.18	3.08	2.94	2.83	2.77	2.84	2.71	2.35	2.24	2.18	2.66	3.42	2.76
3	*Ficus religiosa* L.	4.22	4.18	4.16	4.1	4.08	3.98	3.87	3.72	3.66	3.46	3.82	4.03	3.94
4	*Ficus benghalensis* L.	4.87	4.85	4.81	4.73	4.69	4.51	4.58	4.41	4.36	4.29	4.52	4.71	4.61
5	*Azadirachta indica* A.Juss.	3.24	3.16	3.46	3.28	3.25	3.12	2.98	2.84	2.47	2.36	2.86	3.14	3.01
6	*Monoon longifolium* (Sonn.) B.Xue & R.M.K.Saunders	2.83	2.77	2.64	2.72	2.55	2.67	2.34	2.42	2.32	2.18	2.46	2.76	2.55
7	*Senna siamea* (Lam.) H.S.Irwin & Barneby	4.08	4.16	4.22	3.98	4.1	3.98	3.76	3.62	3.56	3.16	3.42	3.84	3.82
8	*Delonix regia* (Bojer ex Hook.) Raf.	2.92	2.8	2.83	2.78	2.75	2.67	2.48	2.35	2.28	1.94	2.41	2.83	2.58
9	*Dalbergia sissoo* Roxb. ex DC.	3.98	3.75	3.67	3.66	3.52	3.47	3.66	3.51	3.34	3.15	3.66	3.72	3.59
10	*Samanea saman* (Jacq.) Merr.	3.92	3.94	3.82	3.78	3.74	3.7	3.59	3.62	3.47	3.4	3.49	3.78	3.68
11	*Pongamia pinnata* (L.) Pierre	2.92	2.94	2.84	2.76	2.7	2.69	2.58	2.56	2.46	2.36	2.5	2.86	2.68
12	*Eucalyptus tereticornis* Sm.	2.62	2.54	2.48	2.35	2.22	2.14	2.06	1.9	1.48	1.33	1.66	2.34	2.09
13	*Millingtonia hortensis* L.f.	3.66	3.45	3.42	3.37	3.33	3.26	3.23	3.15	2.95	2.87	3.15	3.46	3.27

The Total Chlorophyll Content (TCC) of selected plant species varied across seasons, with the highest average values recorded in *Ficus benghalensis* L. (4.87 mg g^{-1} FW) and the lowest in *Eucalyptus tereticornis* Sm. (1.33 mg g^{-1} FW). Chlorophyll content was highest during the monsoon season and decreased in winter and summer due to pollution, temperature stress, and reduced sunlight. The monsoon season's high chlorophyll levels may be attributed to rain washing off pollutants, enhancing photosynthesis. In contrast, winter's low chlorophyll levels were likely due to higher pollution and environmental stress. This seasonal variation highlights the impact of pollution and climate on plant physiology

Table 2 shows Concentration of Ascorbic acid (mg/gm) of different tree species at Nasik MIDC Area, Nasik (August 2022 to July 2024)

S. N.	Tree Species	Aug. 2022	Sep.2022	Oct.2022	Nov. 2022	dec.2022	Jan.2023	Feb.2023	Mach. 2023	Apr.2023	May. 2023	June. 2023	July. 2023	Average
1	*Terminalia catappa* L.	2.82	2.79	2.94	2.81	2.78	2.76	2.98	3.14	3.22	3.51	3.1	2.98	**2.98**
2	*Mangifera indica* L.	1.65	1.49	1.54	1.88	1.96	1.92	1.76	1.94	2.1	2.08	1.92	1.75	1.83
3	*Ficus religiosa* L.	3.44	3.32	3.4	3.78	4.64	4.12	4.16	4.32	4.22	4.1	3.66	3.56	**3.89**
4	*Ficus benghalensis* L.	3.84	3.98	4.1	4.16	4.08	4.33	4.15	4.18	4.22	4.36	4.21	4.07	4.13
5	*Azadirachta indica* A.Juss.	2.13	2.35	2.44	2.54	2.51	2.84	2.91	3.12	3.66	3.48	3.25	3.1	2.86
6	*Monoon longifolium* (Sonn.) B.Xue & R.M.K.Saunders	1.83	1.84	1.87	1.88	1.93	2.1	2.09	2.14	2.31	2.52	2.17	1.87	2.04
7	*Senna siamea* (Lam.) H.S.Irwin & Barneby	2.84	2.76	2.6	1.74	2.12	2.1	2.64	2.78	3.12	3.2	2.98	2.8	2.64
8	*Delonix regia* (Bojer ex Hook.) Raf.	1.52	1.47	1.66	1.61	1.78	1.83	1.92	2.13	2.2	2.41	2.36	2.14	1.91
9	*Dalbergia sissoo* Roxb. ex DC.	1.96	1.96	1.97	2.13	2.24	2.32	2.4	2.44	2.42	2.54	2.31	2.07	2.23
10	*Samanea saman* (Jacq.) Merr.	3.22	3.12	3.29	3.54	3.64	3.46	3.54	3.6	3.61	3.72	3.58	3.34	3.42
11	*Pongamia pinnata* (L.) Pierre	1.62	1.6	1.78	1.76	1.8	1.8	2.12	2.22	2.34	2.38	2.22	2.2	1.98
12	*Eucalyptus tereticornis* Sm.	1.23	1.39	1.45	1.62	1.71	1.73	1.95	2.06	2.24	2.4	2.1	1.8	1.8
13	*Millingtonia hortensis* L.f.	2.1	2.16	2.4	2.53	2.56	2.64	2.56	2.78	2.82	2.97	2.42	2.14	2.5

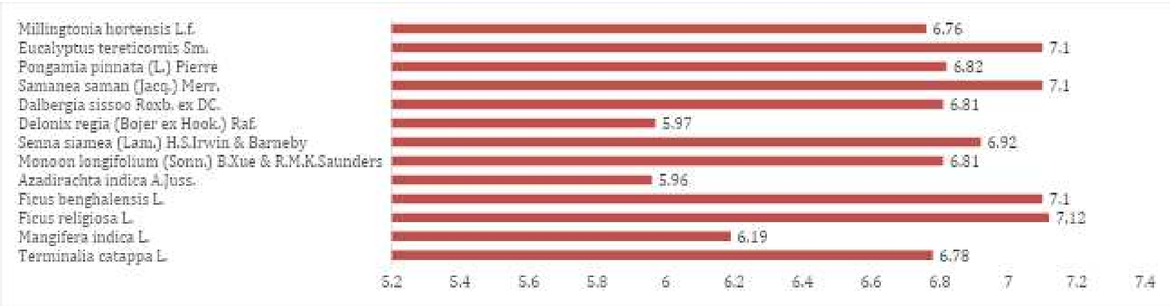


Ascorbic Acid: The **graphical illustration** depicts the **leaf ascorbic acid content** in selected plant species across **summer, monsoon, and winter seasons**. Ascorbic acid levels were highest during **summer**, followed by **winter** and then **monsoon**. As a crucial **reducing agent**, ascorbic acid plays a key role in **cell wall synthesis, defense mechanisms, and cell division** (Conklin, 2001) {11}. Among the studied species, the **highest ascorbic acid content** was recorded in ***Ficus religiosa*** L. (**4.64 mg/gm**), while the **lowest** was observed in *Eucalyptus tereticornis* Sm. (**1.23 mg/gm**).

Table 3 shows: Concentration of pH of different tree species at Nasik MIDC Area, Nasik (August 2022 to July 2024)

S. N.	Tree Species	Aug. 2022	Sep.2 022	Oct.2 022	Nov. 2022	dec.2 022	Jan.2 023	Feb.2 023	Mach. 2023	Apr.2 023	May. 2023	June. 2023	July. 2023	Aver age
1	*Terminalia catappa* L.	7.18	7.16	6.94	6.84	6.82	6.7	6.78	6.6	6.58	5.94	6.68	7.16	6.78
2	*Mangifera indica* L.	6.7	6.34	6.22	6.82	6.31	6.2	6.2	5.9	5.9	5.4	5.8	6.5	6.19
3	*Ficus religiosa* L.	7.26	7.18	7.08	7.16	7.18	7.2	7.1	7.08	6.94	6.84	7.2	7.26	7.12
4	*Ficus benghalensis* L.	7.14	7.16	7.31	7.25	7.1	7.3	7.13	7.04	6.98	6.54	7.08	7.2	7.1
5	*Azadirachta indica* A.Juss.	6.2	6.13	6.04	6.08	6.1	6.1	6.3	6.1	5.54	5.12	5.66	6.22	5.96
6	*Monoon longifolium* (Sonn.) B.Xue & R.M.K.Saunders	7.24	7.2	6.6	6.46	7.4	6.78	6.89	6.74	6.34	6.4	6.88	6.82	6.81
7	*Senna siamea* (Lam.) H.S.Irwin & Barneby	6.92	7.1	7.04	7.1	6.92	6.94	6.84	6.82	6.82	6.72	6.91	6.94	6.92
8	*Delonix regia* (Bojer ex Hook.) Raf.	6.12	6.34	6.5	6.2	6.2	6.08	6.04	5.8	5.3	5.6	6.1	5.4	5.97
9	*Dalbergia sissoo* Roxb. ex DC.	6.94	6.92	7.1	6.88	6.67	6.78	6.94	6.86	6.56	6.44	6.72	6.96	6.81
10	*Samanea saman* (Jacq.) Merr.	7.22	7.22	7.18	7.16	7.21	7.14	7.1	6.94	6.92	6.87	7.14	7.18	7.1
11	*Pongamia pinnata*	7.1	6.92	6.86	6.9	6.82	6.78	6.82	6.7	6.6	6.58	6.82	6.98	6.82

	(L.) Pierre													
12	*Eucalyptus tereticornis* Sm.	7.22	7.2	7.22	7.18	7.14	7.16	7.12	7.14	6.84	6.9	6.94	7.14	7.1
13	*Millingtonia hortensis* L.f.	7.12	7.08	7.1	6.92	6.78	6.66	6.57	6.5	6.2	6.6	6.74	6.92	6.76



pH: The **leaf pH values** of the selected plant species across different seasons are illustrated in **Graph 3**. Leaf pH was **highest during the monsoon**, gradually **decreased in winter**, and reached its **lowest level in summer**. The presence of **acidic pollutants** can shift cell sap pH toward acidity, potentially reducing the efficiency of **hexose sugar conversion to ascorbic acid**. Since the **reducing activity of ascorbic acid** is **higher at elevated pH and lower at acidic pH**, plants with **higher leaf extract pH** exhibit **greater tolerance to air pollution** (Agrawal, 1997) {1}.

Table 4 shows: Concentration of Relative water content of different tree species at Nasik MIDC Area, Nasik (August 2022 to July 2024)

S. N.	Tree Species	Aug. 2022	Sep.2022	Oct.2022	Nov. 2022	Dec.2022	Jan.2023	Feb.2023	Mach. 2023	Apr.2023	May. 2023	June. 2023	July. 2023	Average
1	*Terminalia catappa* L.	83.56	81.94	80.46	78.92	77.25	76.47	76.14	74.94	75.22	76.12	78.56	82.88	78.53
2	*Mangifera indica* L.	84.84	84.08	83.46	82.3	80.14	80.56	79.25	77.36	76.14	74.26	76.94	79.88	79.93
3	*Ficus religiosa* L.	90.84	91.12	89.44	86.35	86.88	85.47	85.99	84.66	83.25	80.68	85.24	87.24	86.43
4	*Ficus benghalensis* L.	94.66	94.78	93.64	92.82	92.74	91.24	90.78	89.27	89.24	87.46	91.24	93.12	91.74
5	*Azadirachta indica* A.Juss.	86.84	85.13	83.74	80.92	79.67	78.18	78.14	77.13	74.26	72.76	75.14	82.56	79.53
6	*Monoon longifolium* (Sonn.) B.Xue & R.M.K.Saunders	87.24	85.48	85.44	83.14	83.25	82.17	80.12	80.34	79.25	78.12	82.14	85.78	82.7
7	*Senna siamea* (Lam.) H.S.Irwin & Barneby	89.08	91.12	89.45	88.25	86.46	83.51	80.12	78.64	77.24	75.22	79.24	85.46	83.64

8	*Delonix regia* (Bojer ex Hook.) Raf.	84.26	83.42	81.54	80.48	78.66	77.88	78.14	76.14	75.94	74.12	77.23	80.56	79.03
9	*Dalbergia sissoo* Roxb. ex DC.	85.88	84.23	83.48	83.78	84.12	82.4	80.18	78.06	77.24	76.38	79.16	83.78	81.55
10	*Samanea saman* (Jacq.) Merr.	93.88	92.94	93.45	92.46	90.68	89.56	87.92	87.22	86.92	84.56	89.66	92.74	90.16
11	*Pongamia pinnata* (L.) Pierre	83.82	82.14	80.78	81.46	78.12	78.46	76.88	76.44	75.22	74.98	77.24	80.12	78.8
12	*Eucalyptus tereticornis* Sm.	80.1	78.2	77.22	75.32	74.66	72.48	73.12	73.56	72.14	72.36	75.14	77.16	75.12
13	*Millingtonia hortensis* L.f.	92.84	90.36	88.23	87.86	85.62	83.92	82.94	81.9	80.88	79.48	84.78	89.12	85.66

Relative Water Content: The **relative water content (RWC)** of the studied plant species was **highest during the monsoon**, followed by a **decline in winter** and the **lowest levels in summer**, as illustrated in **Graph 4**. RWC represents the **water content in a leaf relative to its full turgidity** and is closely linked to **protoplasmic permeability** (Agrawal & Tiwari, 1997) {1}. Increased permeability leads to **water and nutrient loss**, accelerating **leaf senescence**. Plants with **higher RWC under polluted conditions** may exhibit **greater tolerance to air pollutants**.

Graph 4 : Concentration of Relative water content of different tree species at Nasik MIDC Area, Nasik (August 2022 to July 2024)

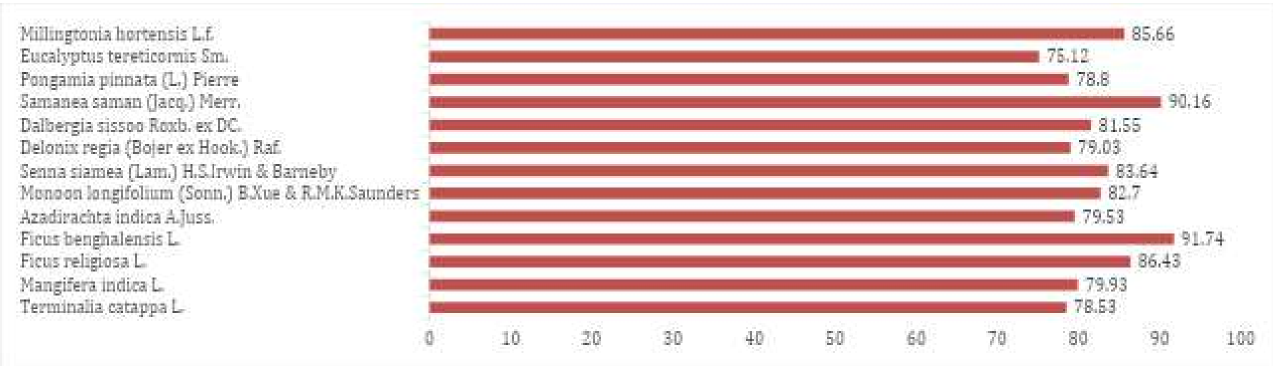
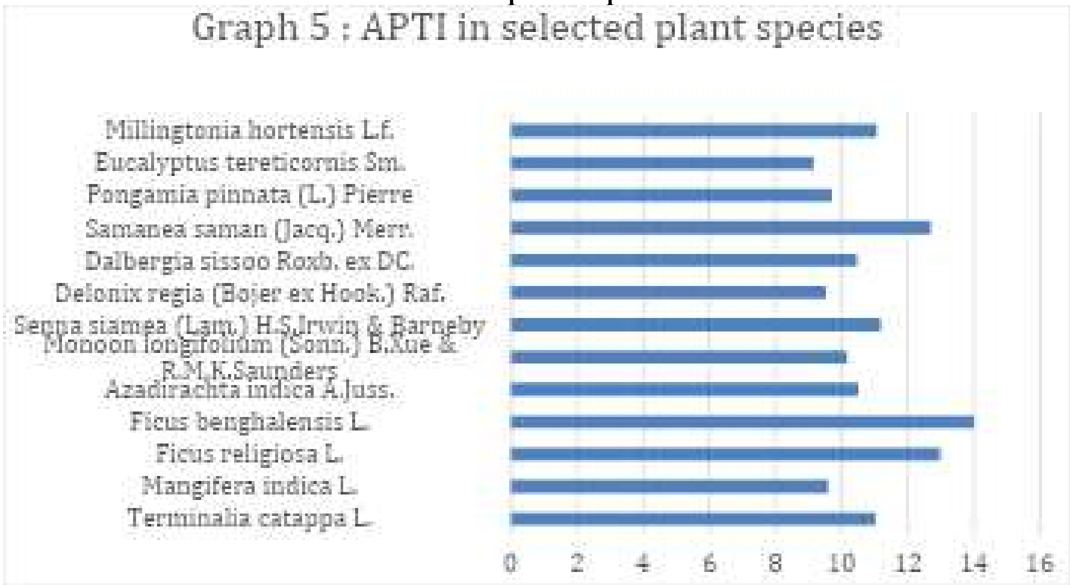


Table 5 shows: APTI in selected plant species



Sr.No	Tree Species	APTI
1	*Terminalia catappa L.*	11.03
2	*Mangifera indica L.*	9.59
3	*Ficus religiosa L.*	12.98
4	*Ficus benghalensis L.*	**14.01**
5	*Azadirachta indica A.Juss.*	10.51
6	*Monoon longifolium (Sonn.) B.Xue & R.M.K.Saunders*	10.17
7	*Senna siamea (Lam.) H.S.Irwin & Barneby*	11.19
8	*Delonix regia (Bojer ex Hook.) Raf.*	9.53
9	*Dalbergia sissoo Roxb. ex DC.*	10.47
10	*Samanea saman (Jacq.) Merr.*	12.7
11	*Pongamia pinnata (L.) Pierre*	9.7
12	*Eucalyptus tereticornis Sm.*	**9.16**
13	*Millingtonia hortensis L.f.*	11.07

APTI: The **Air Pollution Tolerance Index (APTI)** values for each plant species across different seasons are illustrated in **Graph 5**. Among the studied species, **Ficus benghalensis** L. exhibited the **highest APTI** value of **14.01**, followed by **Ficus religiosa** L. (**12.98**). In contrast, the **lowest APTI value** (**9.16**) was recorded in *Eucalyptus tereticornis* Sm., indicating its higher sensitivity to air pollution.

Conclusion: The Air Pollution Tolerance Index (APTI) assessment of selected tree species in the industrial areas of Nasik revealed significant variability in plant susceptibility to air pollution. Species exhibiting higher APTI values were categorized as tolerant, while those with lower values were classified as sensitive. Additionally, the sensitivity of plants to pollutants varied between shrubs and trees, suggesting the need for distinct indices tailored to different plant types (Singh & Rao, 1983).

Among the species studied, *Ficus benghalensis* L. (14.01) demonstrated the highest tolerance to automobile and industrial pollutants, while *Eucalyptus tereticornis Sm.* (9.16) showed high susceptibility. This differential susceptibility may be attributed to certain species' greater capacity to accumulate dust, which in turn induces biochemical and physiological alterations (Singh, 2005).

These findings underscore the potential of plants as bio-indicators of air pollution, positioning them as valuable tools for environmental monitoring and green belt development. The study emphasizes the critical role of bio-monitoring in assessing the effects of pollution on urban vegetation, thereby supporting sustainable urban planning initiatives.

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