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Physiological Impact of Automobile Emissions and Air Pollution Tolerance of Selected Roadside Plants in Solapur City, Maharashtra

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Abstract

Physiological effect of automobile pollution and air pollution tolerance of Eight species grown along the roadside in Solapur city and compared with controlled area of Police head quarter and Walchand College campus in Solapur city. Physiological effect on Chlorophyll, pH of leaf extract Ascorbic acid content and relative water content (RWC) with respect to air pollution tolerance index of plant was studied. The present study assesses biochemical and physiological characteristics to evaluate APTI in Solapur district of Maharashtra. The API was assessed based on calculated APTI and socio-economic features of a selected common tree species along the roadside at different sites. According to APTI, Ziziphus jujuba, Tamarindus indica and Carica papaya were the most tolerant species, while Azadirachta indica, Nerium spp. and Annona squamosa were intermediately tolerant towards air pollution. According to API the Ziziphus jujuba and Tamarindus indica populations were excellent and best among all the studied sites. So, the air pollution-resistant tree species can be suggested for roadside plantations for the development of green belt areas in urban regions.

Keywords: *Physiology, APTI, Solapur district, Pollution.*

Introduction

Air pollution refers to the introduction of chemicals, particulate matter, or biological agents into the atmosphere by human activities, causing harm or discomfort to humans and other living organisms, or leading to environmental damage (Anonymous, 2008). The atmosphere constitutes a highly dynamic and intricate gaseous envelope essential for sustaining life on Earth. However, the presence of certain chemical constituents within this system can exert detrimental effects on both plant and animal health. Among the major environmental concerns linked to rapid industrial development is air pollution, which results from the release of harmful substances into the atmosphere. These atmospheric contaminants are broadly categorized into two types: primary pollutants, which are directly emitted from sources such as industrial processes and combustion activities, and secondary pollutants, which are generated through chemical transformations of primary pollutants under atmospheric conditions. Pollutants that are pumped into the atmosphere and directly pollute the air are called primary pollutants while those that are formed in the air when primary pollutants react or interact are known as secondary pollutants (Anonymous, 2008). Air pollutants can directly affect plants via leaves or indirectly via soil acidification (Steubing et al., 1989). It has also been reported that when exposed to air pollutants, most plant experience physiological changes before exhibiting visible damage to leaves (Dohmen et al., 1990). Previous studies also showed the impact of air pollution on ascorbic acid content (Hoque et al., 2007), chlorophyll content (Flowers et al., 2007), leaf extract pH (Klumpp et al., 2000) and relative water content (Rao, 1979). These separate parameters gave conflicting results for same species (Han et al., 1995). However, the air pollution tolerance index (APTI) based on all four parameters has been used for identifying tolerance levels of plants species (Singh and Rao, 1983; Singh et al., 1991). Several contributors agree that air pollutants effect plant growth adversely (Horsfall, 1998, Henry and Heinke, 2005; Rao, 2006, Bhatia, 2006). Air pollution tolerance index is used by landscapers to select plant species tolerance to air pollution (Yan-Ju, 2008). The present study aims to evaluate the Air Pollution Tolerance Index (APTI) values of eight plant species within Solapur city located in the Maharashtra state of India.

Materials and methods:

1. **Area of study:**

The present study was conducted along the Market yard to Boramani naka route within Solapur city located in southeastern region of Maharashtra, India.

Solapur lies at 17.6701^0 N latitude, 75.9010^0 E longitude with an average elevation of 458 m above mean sea level. The district is bordered by Ahmednagar to the north; Osmanabad to the northeast. Gulbarga (Renamed as Kalaburagi) and Bijapur district of Karnataka state to the northeast and south respectively. Solapur is located about 410 km from Mumbai the state capital and is well connected by both road and rail network.

Climatically, Solapur falls under the dry (arid to semi-arid) zone and experiences three distinct seasons i.e., summer, monsoon and winter. The summer season (March to May) is typically characterized by high temperatures ranging from 30°C to 40°C. The monsoon season (June to September) brings moderate rainfall, with an average annual precipitation of approximately 545 mm. The winter season (November to February) is relatively mild with temperatures occasionally dropping below 10°C.

Since the biochemical constituents of plant tissues may vary diurnally, all plant samples were collected at a fixed time of day to ensure data consistency. The samples were promptly transported to the laboratory for subsequent processing and analysis.

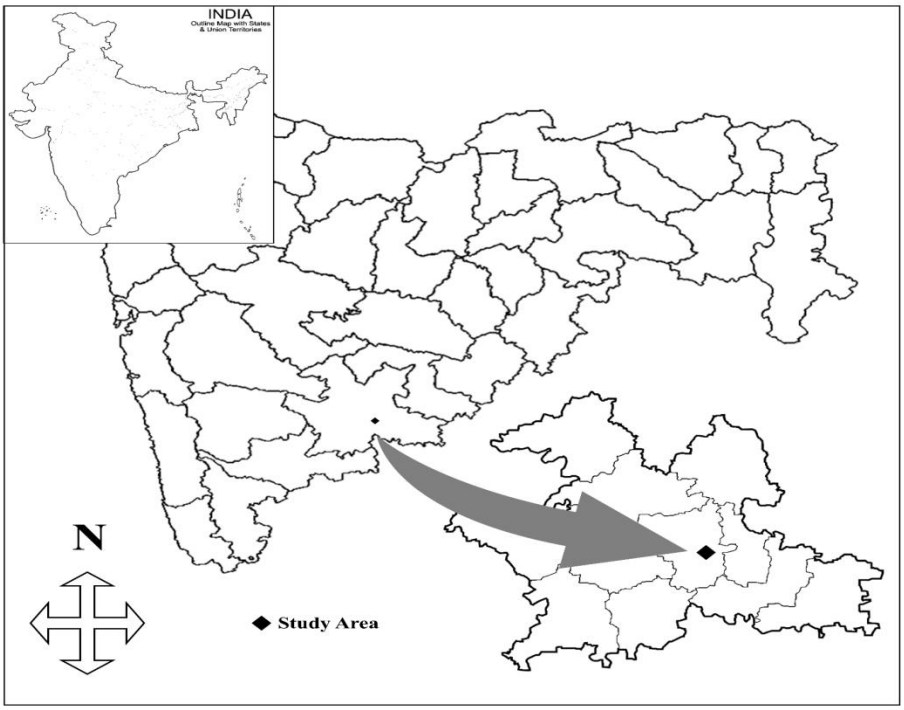


Fig. 1 Geographical locations of sampling sites

2. **Relative leaf water content (RWC):**

RWC was measured by Following the standard literature described by Singh (1977). The fresh weight of the leaves was recorded immediately after collection. The leaves were then soaked in water overnight, blotted to remove surface moisture, and weighed to obtain their saturated weight. Afterwards, the same leaf samples were dried in a hot-air oven at 80 °C for 24 h to determine their oven-dry weight. Leaf RWC was determined and calculated with the formula:

$$\text{Relative water content (\%)} = \frac{\text{Fresh weight} - \text{Dry Weight}}{\text{Turgid weight} - \text{Dry Weight}} \times 100$$

3. **Total chlorophyll content (TCC)**:

The total chlorophyll content (TCC) was done by following the procedure described by Arnon (1949). Approximately 3 g of fresh leaf material was homogenized and extracted with 10 mL of 80% acetone (w/v) then allowed to stand for 15 minutes for pigment reaction completion. The extract was decanted into a clean test tube and centrifuged at 2500-3000 rpm for 10 minutes. The resulting supernatant was carefully collected and absorbance was recorded at 645 nm and 663 nm using a spectrophotometer. The chlorophyll content was calculated using formula:

$$Total\ chlorophyll\ (mg/g) = \frac{[(20.2 \times A_{645}) + (8.02 \times A_{663}) \times V]}{1000 \times W}$$

A= Absorbance; V= Volume of extract; W = Fresh leaf weight in gram.

4. **Ascorbic acid (AA) determination:**

The ascorbic acid content (mg g^{-1}) was quantified by employing the spectrophotometric technique described by Bajaj and Kaur (1981). Precisely add 1 g of plant samples in 4 mL of oxalic acid–EDTA extraction solution. After that, 1 mL o-phosphoric acid and 1 mL of 5 % tetraoxosulphate acid were added, followed by 2 mL ammonium molybdate with 3 mL distilled water. The reaction mixture was incubated for 15-20 min at room temperature, after absorbance was measured at 760 nm using a spectrophotometer. Ascorbic acid concentration (mg/g) was determined by interpolation from a standard calibration curve prepared with known ascorbic acid concentrations.

$$Ascorbic\ acid\ (mg/g) = [E_0 - (E_s - E_t)] \times \frac{V}{W \times V_1 \times 1000}$$

V= Mixture volume; W= Fresh leaf weight; V_1= Supernatant Solution volume.

5. **APTI Determination:**

The Air Pollution Tolerance Index (APTI) of eight commonly occurring plant species was studied using standard procedure described by Singh and Rao (1983). The Air Pollution Tolerance Index (APTI) was calculated using the following formula:

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

A = Ascorbic acid content (mg g^{-1}); T = total chlorophyll (mg g^{-1}); P = pH of leaf extract;
R = relative water content of leaf (%).

Sr. No.	Plant Species	TCC (mg/g FW)	pH	AA (mg/g FW)	RWC (%)	APTI	TCC (mg/g FW)	pH	AA (mg/g FW)	RWC (%)	APTI
		Controlled area					Polluted area				
1	*Annona squamosa* L.	7.8	7.0	1.1	91.0	9.3	7.0	6.5	1.3	80.0	5.7
2	*Azadirachta indica* A. Juss.	5.0	6.5	3.7	74.4	8.7	4.9	6.3	3.8	70.0	7.5
3	*Carica papaya* L.	6.4	6.5	1.5	80.0	9.9	6.3	6.0	1.6	70.0	8.9
4	*Nerium* spp.	4.3	6.6	5.8	74.0	9.9	3.0	6.1	6.0	52.0	9.0
5	*Pongamia pinnata* var. minor (Benth.) Domin	7.7	6.0	0.5	85.9	10.7	6.3	5.2	0.6	50.0	9.8
6	*Tamarindus indica* L.	9.6	6.0	2.2	80.0	11.4	8.3	5.9	2.8	75.0	10.6
7	*Vachellia nilotica* (L.) P.J.H.Hurter & Mabb.	8.0	6.3	2.2	68.2	13.7	6.3	6.0	2.3	60.0	10.6
8	*Ziziphus jujuba* Mill.	7.2	3.3	0.9	78.4	11.7	7.2	3.0	0.7	68.2	11.2

Table 1. Comparison between biological parameters of plant species in controlled and polluted areas

Results:

The results showed that the selected plant species exhibited disparity responses to air pollution, as reflected in their physiological and biochemical parameters (**Table 1**). The variation in APTI values was attributable to differences in the four contributing factors i.e., total chlorophyll content, leaf extract pH, ascorbic acid content and relative water content which sometimes exhibited contrasting trends consistent with former findings (Han et al., 1995).

1. **Total Chlorophyll Content (TCC):**

The highest TCC under control conditions was observed in *T. indica* (9.6 mg g^{-1} FW), however the lowest was recorded in *Nerium* spp. (4.3 mg g^{-1} FW). The greatest drop in TCC between control and polluted sites was seen in *V. nilotica* (1.7 mg g^{-1} FW), while *Z. jujuba* showed no change.

2. **Leaf Extract pH:**

pH was highest in *A. squamosa* (7.0) under control conditions and lowest in *Z. jujuba* (3.3). The largest pH decline between sites was observed in *P. pinnata* (0.8), whereas *T. indica* and *Z. jujuba* showed minimal differences (0.1 and 0.3, respectively).

3. **Ascorbic Acid Content (AA):**

Nerium spp. exhibited the highest AA content under control conditions (5.8 mg g^{-1} FW), whereas *P. pinnata* had the lowest (0.5 mg g^{-1} FW). AA levels showed relatively minor changes across sites, with slight increases observed in most species (e.g., *T. indica* from 2.2 to 2.8 mg g^{-1} FW).

4. **Relative Water Content (RWC):**

The highest RWC was recorded in *A. squamosa* (91.0%) while the lowest occurred in *V. nilotica* (68.2%). The most pronounced reduction in RWC between sites was seen in *P. pinnata* (35.9%), whereas *T. indica* displayed a modest reduction (5%).

5. **Air Pollution Tolerance Index (APTI):**

Among the studied species, *V. nilotica* exhibited the highest APTI under control conditions (13.7), followed closely by *T. indica* (11.4) and *Z. jujuba* (11.7). The lowest APTI value was observed in *A. squamosa* (5.7) at the polluted site. The maximum decline in APTI between sites was found in *V. nilotica* (3.1), indicating greater sensitivity, whereas *Z. jujuba* exhibited the smallest change (0.5), suggesting higher tolerance.

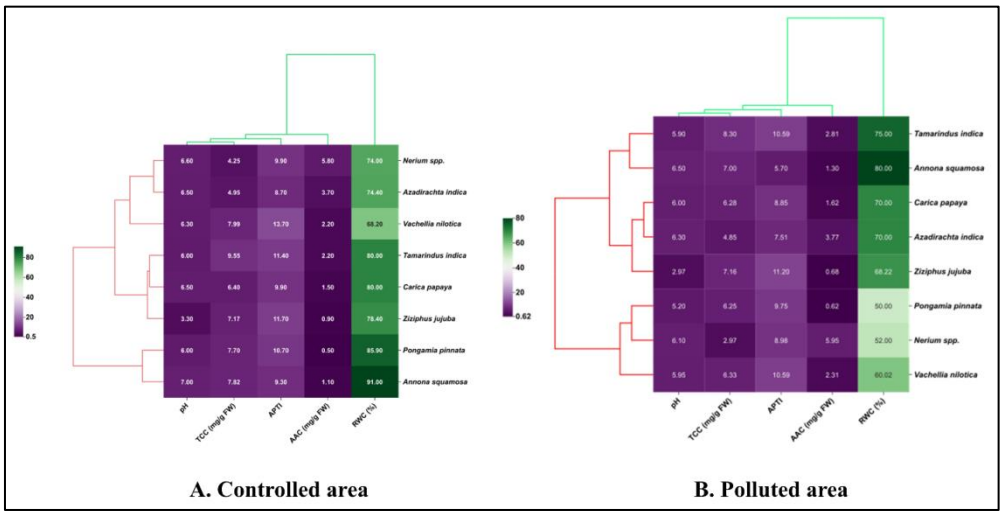


Fig. 2: Cluster heat maps of plants with their APTI elements in studied area.

Conclusions:

The present study demonstrates that the air pollution tolerance (APTI) varies significantly among the eight investigated plant species. *V. nilotica*, *T. indica* and *Z. jujuba* exhibited relatively high APTI values, suggesting their potential as tolerant species suitable for greenbelt development and urban plantation programs aimed at mitigating air pollution. In contrast, *A. squamosa* and *Azadirachta indica* showed lesser APTI values, indicating their sensitivity to vehicular and industrial emissions and their possible role as bioindicators of air quality deterioration.

The heatmap analysis (**Figure 2**) clearly demonstrates that air pollution significantly alters the physiological and biochemical attributes of the studied plants. Species such as *Z.jujuba*, *T. indica* and *C. papaya* exhibit relatively higher APTI values and cluster closely together, signifying their tolerance and potential for urban greenbelt development. Conversely, *P. pinnata* and *V. nilotica* displayed sharp declines in TCC, RWC and APTI grouped in pollution-sensitive species that may serve as effective bioindicators. The data confirm that APTI and clustering approaches are reliable tools to differentiate tolerant species from sensitive ones and can guide the selection of plants for air pollution mitigation and biomonitoring programs.

Overall, the findings highlight that the variation in APTI is influenced by multiple physiological parameters, including TCC, leaf extract pH, ACC and RWC. These results reinforce the usefulness of APTI as a reliable tool for selecting tolerant plant species for environmental management and for monitoring the biological impact of air pollutants on vegetation.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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