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Research Article

Effects of Automobile Emission on Morphology and Anatomy of the *Mangifera indica* L. Fruit Tree at District Samastipur, Bihar, India

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Abstract

Automobile transportation has been strongly associated with air pollution throughout various stages, like driving, fueling, production, and disposal. The emissions released from vehicle exhaust contain substantial quantities of detrimental gases, including carbon compounds, hydrocarbons, nitrogen oxides (NOx), volatile organic compounds (VOCs), and particulate matter. The reduced fertility of plants is a consequence of intense air pollution. The toxic gases emitted from vehicles endanger plants and cause changes in the physical and structural development of the *Mangifera indica* L. tree. This study aimed to explore the harmful effects of vehicle emissions on the physical structure and anatomy of Mango trees in the Samastipur district of Bihar, India. The experiment was based on the comparative study of under one year examination (2021-2022). Polluted and non-polluted sites were chosen and study was done. The result indicated that the automobile air pollution was hindering the healthy growth of *Mangifera indica* L.

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Introduction

Plants have ubiquitous and paramount significance in life of human since emergence of life on planet. Plants have been used as source of food, fodder, medicines, shelter, and aesthetics (Ishtiaq et al. 2017). Pollination is a distinctive feature of flowering plants. It operates by transferring pollen grains from one flower to the female stigma. The ultimate goal of all living organisms, including plants, is to generate offspring to ensure the continuity of the species. Angiosperms accomplish this by producing seeds. Seeds possess the genetic material required for the development of a new plant. The formation of seeds occurs through the transfer of pollen among the flowers belonging to the identical species. Pollen grains, characterized by their dusty and powdery texture, typically have a spherical shape and a diameter ranging from 25 to 50 micrometers. Pollen grains are responsible for fertilization and the fertility of plants. The amount of emissions in the air has risen because of the exponential growth in industrialization and urbanization (Shakeel et al. 2022). Although rapid industrialization and urbanization has resulted in a boom of the economy of our country, it has also contributed significantly in enhancing the problems of plant health. Vehicular exhaust adds up huge amounts of soot particles, smoke, poisonous gases like SO_2, NO_2, CO_2, and VOCs etc., heavy metals and organic molecules on the roads all over the world. All these air pollutants are known to produce adverse effects on the health of plants, animals and humans (Kaur and Nagpal 2017). Plants acts as a natural filters of air pollution either by stomatal uptake or the deposition on the surfaces of leaves. Air pollutant absorbed through stomata undergoes various interactions and enhances the tolerance capacity of the plant to fight against the stress. All these interactions lead to different biochemical, physiological and anatomical responses in plants (Tak and Kakde 2020). Air pollution due to vehicle exhaust causes irregularity in anthers, decreases the number and masculine infertility. The chemical pollutants produced by industries and traffic

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emissions not only put damaging effects on morphological and physiological parameters of plants but also comprise alterations and chromosomal impairment. These irregularities are contingent on ecological and hereditary issues and may eventually go to alteration in propagative capability of plant species. The air pollution adversely impacts the photosynthetic pigment and consequently reduces productivity. Leaf chlorophyll, carotene, proline, and proteins are found to be influenced adversely by air pollutants (Singh et al 2020). The air pollution influences stomatal functioning and leaf thickness of urban plantation. Ascorbic acid is one of the strong indicators of stress and is found to be related to air pollution levels Several investigations have indicated vehicular emission effects on plant leaves stomatal apertures, viability of pollen and development of plants (Leghari et al 2018). Many studies have shown effects of automobile emissions on leaves, stomatal apertures, and pollen viability and growth patterns of plants (Kaur and Nagpal 2017). Chlorophyll measurement is an important tool to evaluate the effects of air pollutants on plants as it plays an important role in plant metabolism and any reduction in chlorophyll content corresponds directly to plant growth (Wagh et al. 2006). Leaf chlorophyll content and carotenoids thus can provide valuable information about physiological status of plants (Joshi and Swamy2009). When flower buds release pollen grains into the air that is contaminated with pollutants, the grains absorb both moisture and specific pollutants. Pollen grains' viability and plant reproduction are adversely impacted by the existence of contaminants such as heavy metals, fluorides, and pesticides on their surfaces. Palynoindication, as one of the promising and new methods of the assessment of quality of the environment, is based on determination of the proportions of normal and abnormal pollen, when the quality of environment assessed by the share of normal pollen in the samples (Vasilevskaya 2022). The main aim and objective of this study was to explore the impact of automobile emissions on the physical characteristics and internal structure of *Mangifera Indica L.* fruit trees in the Samastipur district, Bihar. This work aimed to demonstrate the extent of damage caused by vehicle exhaust pollution on the fruit-bearing plants *of M. indica L.* by examining various aspects of plant organs.

Materials and Methods

Study Area

Urban areas of Samastipur district are extremely very much polluted due to vehicular exhaust pollution (Table 1). Trees act as an important and cost-effective solution to combat air pollution. However, different trees have varying levels of combating capacity distinguished with their adaptation and mitigation potential. Urban green belts or urban roadside plantation act as a sink for particulate and gaseous emissions in a city and are often termed as "the lungs of the City". Trees act as a sink for CO_2 by fixing carbon during photosynthesis and storing carbon as biomass. Thus, the roadside plantations are expected to combat air pollution (Singh et al. 2020). The city area of Samastipur town and the rural village of the Satmalpur was selected to calculate the effect of automobile emissions on pollen grains of *M. indica* L (Fig. 1). The distance between Samastipur towns to the Satmalpur village is approximately 7 km. Mango, Lychee, Banana and Guava trees and some flowering plants like hibiscus, sunflower and rose, orchid was grown.

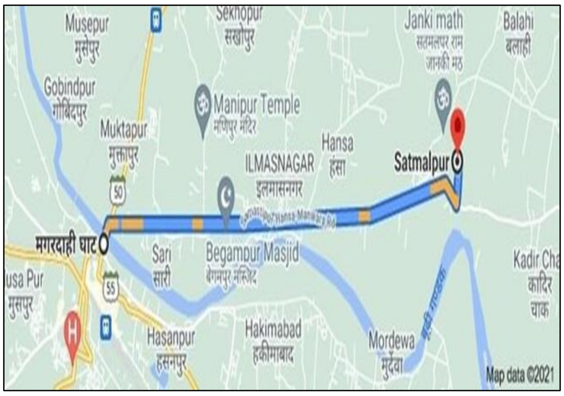

Figure 1. Google Map of Study Area

Table 1. The Air Quality Index of Samastipur

Level of Air pollution	Air quality index	Main pollutant
Very unhealthy	140* US AQI	PM2.5

The climate of the Study Area

Indo-Gangetic Plains (IGP) witnessed the green revolution and is amongst the world's most fertile alluvium (Mishra et al. 2022). The area of samastipur district is 2,904 square kilometers. The samastipur is situated in the Bihar state of India. It is surrounded by different geographical features. It is bordered by the Bagmati River in the north, which separates it from Darbhanga district. To the west, it shares boundaries with Vaishali and a portion of the Muzaffarpur district. The river Ganges marks the southern border, while the eastern boundary is formed by Begusarai and a portion of the Khagaria district. Main administrative center of the district is situated in the town of Samastipur. The area is crisscrossed by multiple rivers, namely Budhi Gandak, Baya, Kosi, Kamla, Kareh, Jhamwari, and Balan, all of which flow into the Burhi Gandak River. Furthermore, the Ganges runs alongside the district's southern border. Samastipur is positioned at 25°55'N latitude and 85°50'E longitude. Agriculture serves as the predominant economic activity in the district, supporting around 83% of the working population. Floriculture is also a significant source of income. Samastipur is situated in the North-West Alluvial plains, which is designated as agro-ecological zone-I in the state. The region is renowned for its fertile alluvial soil and the cultivation of Rabi crops. Additionally, Samastipur has historically been a prominent hub for the indigo industry. This region also cultivates wheat, pulses, and edible oil seeds. The soil's texture is sandy loamy and has a sufficient quantity of organic material, which makes it appropriate for cultivating vegetables and spices. The Samastipur district is renowned for its spice production, particularly Turmeric and Garlic. The Turmeric cultivated in this region has the capacity to become a well-known brand worldwide because of its abundant curcumin levels.

Plant Material Collected

The mango (*Mangifera indica L.*) is native to South and Southeast Asia, from where it has been distributed worldwide to become one of the most cultivated fruits in the tropics. It is the national fruit of India. In India, harvest and sale of mangoes take place during March-May and the fruits have high economic value in India **(**Saran et al 2015). Flower sample of *M indica* L. were gathered from both the contaminated and uncontaminated regions within the Samastipur district (Fig. 2). For the polluted area, the sample was taken from the Samastipur Magardahi Ghat road which is a heavily polluted area of the district, for non-polluted areas, Satmalpur village was selected for sample collection which is 7 km away from the Ghat road (Table 2).

Table 2. Name and description of site areas

Site Areas	Distances
Samastipur Magardaahi ghat (polluted area)	15 Km away from city center
Satmalpure Village area (non-polluted area)	7 Km away from Magardaahi ghat

Soil characteristics were similar of both sites. Anthers were collected from plants in a random manner. Statistical analysis was done. The soil samples were taken simultaneously from both the polluted site and the control site. In Table. 3, it is indicated that the soil pH at the polluted site was recorded as 7.2, whereas at the control site, it was slightly lower at 7.1. Additionally, the specific conductivity of the polluted site soil was measured to be 5.30 × 10-4, while at the control site, it was slightly lower at 5.20 × 10-4. The organic matter content in the polluted site soil was found to be 0.3, whereas at the control site, it was slightly higher at 0.4. Both the polluted and control sites exhibited alluvial soil texture. Table 1 shows the unhealthy level of air pollution for plants including all living beings." with a recorded Air Quality Index of 140*. The PM 2.5 was main pollutant. It is a fine particulate matter with a diameter of 2.5 micrometers or less than 2.5 micrometers.

Air Sampling and Analysis

Air quality index (AQI) is used worldwide to inform the public about levels of air pollution (degradation or improvement) and associated to different biological effects. Different types of anthropogenic activity mainly transportation have an enormous impact on the ambient air quality in several ways. The higher the AQI value, the greater the level of air pollution and greater the health concern (Shweta and Jain 2018). Air sampling and analysis were conducted at selected sites. Duration of sampling and analysis was done for one year viz. December 2021 to November 2022. The air quality was analyzed considering parameter like SO_2, NO_2, RSPM and SPM. The State Pollution Control Board in Patna, Bihar monitored air pollutants by collecting

Table 3. Soil samples of the chosen site areas

Experimental Site	Soil Parameter			
	pH level of Soil	**Specified conductivity**	**Organic matters**	**Texture of the soil**
Polluted Site	7.2	5.30×10^{-4}	0.3	*Alluvial Soil*
Control Site	7.1	5.20×10^{-4}	0.4	*Alluvial Soil*

Figure 2. Study Area (The Polluted site and the non-polluted Sites)

data from the SPCB. Air pollutants were quantified at the control site utilizing the RDS APM 460 apparatus. This involved drawing air into a suitable reagent for a period of 24 hours, repeated every 30 days. The APM 460 Respirable Dust Sampler was employed to examine the amount of Suspended Particulate Matter and Respirable Suspended Particulate Matter. It typically functioned with a flow rate that varied between 1.0 and 1.5 cubic meters per minute. Standard methods were followed using preweighed glass fiber filters (GF/A) from the brand Whatman. For the collection of SO_2 (Sulfur Dioxide) and NO_2 (Nitrogen Dioxide), the sample was fizzed through a specialized absorbing solution containing sodium tetrachloromercuate for SO_2 and sodium hydroxide for NOx, at an average flow rate of 0.2-0.5 min^{-1}. Samples collected in the infringe area were promptly placed in the cold closet and transferred to a refrigerator until they were ready to be analyzed.

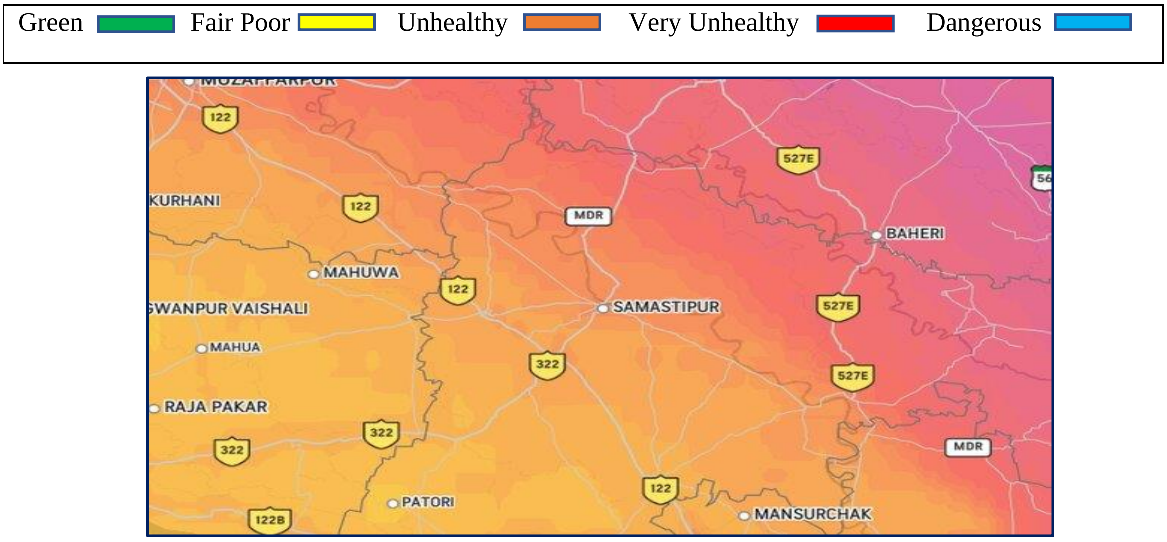

Figure 3. Present air quality of Samastipur

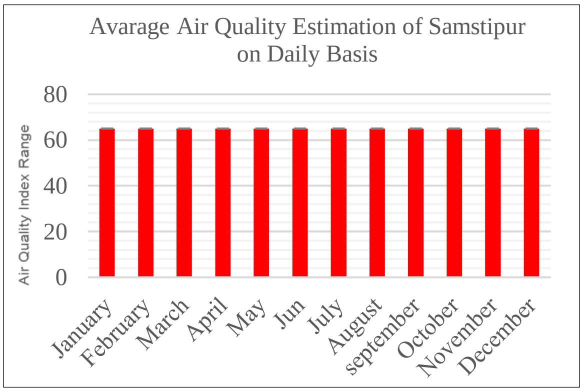

Figure 4. Chart shows the Average Air Quality Index of the City (Daily Basis)

They were then brought to the laboratory on the same day and analyzed immediately to determine their concentration levels. The concentration of NO_x was measured using the Modified Jacobs-Hochheiser method (1958), while SO_2 was measured using the Modified west and Geake method (1956). According to the graph, the air quality in Samastipur is heavily polluted and poses a health risk to sensitive groups, including plants. The measurements of Suspended Particulate Matter and Respirable Suspended Particulate Matter were obtained using filter paper methods. The sampling apparatus was positioned 2 meters above the ground surface. On the basis of collected data on pollutants, the air quality index was calculated.

Sampling and Analysis of plants

Plant sample collection was done to evaluate the consequences of automobile emissions on the morphology and anatomy of the *Mangifera indica* L. fruit tree at district samastipur. Matured leaves or leaflets of the same age and size were collected from the chosen tree plants at the morning time (5am-9 am) and having the same ecological conditions of soil, water and light with extreme caution. Selected plant samples collected from the respective sites were used and wrapped in polythene bags (to minimize evaporation losses). It was brought to the laboratory for further examination. The fresh leaf sample was analyzed for various morphological and anatomical parameters. Air quality parameters were also analyzed during the study period. Fresh leaf samples were obtained from both polluted and control sites, collected from mature and well-aged trees. The samples were gathered from trees, specifically at an elevation ranging from 5 to 8 feet above the earth's surface. The standardized procedure established by Maclachlan and Zalik in 1963 was used to evaluate the amount of chlorophyll-a, chlorophyllv-b, and total chlorophyll. Carotenoid levels were determined using the method described by Duxbury and Yentsch in 1956. Ascorbic acid level was measured utilizing the technique outlined by Sadashivam and Manikam in 1991. For each date of sampling, ten samples were analyzed from every Mango tree.

Morphological changes in plant leaves due to pollution

The leaves of *M. indica* plants of the polluted area were found to be discolored, dusty, and wrinkled when compared to non-polluted area.

Leaf color **-:** The color of leaves was visually observed on randomly collected samples from both reference sites and polluted sites to record their leaf color.

The length and the breadth of the leaf **-:** The ruler was used to measure the size of the leaves selected from both the reference and polluted sites.

Leaf area **-:** The leaf area was determined by measuring the length and width of the leaves and subsequently multiplying those measurements by a fixed factor. Constant was obtained by comparing the leaf area calculated through the paper graph method, which involves measuring the leaf area using a graph paper, with the measured length and width of the leaf.

$$L \times B \times C = \text{Leaf area (A) or } C = A \div L \times B$$

Where, L-length of leaf, B-breadth of leaf, C-constant of the area of leaf, A-the leaf area

The length of the Petiole **-:** The length of the petiole was measured with the help of a ruler.

Micro-Morphological Parameters Examination

Microscopic investigations were performed by preparing a temporary slide of the peeled epidermis from a fully developed leaf. The procedure involved the utilization of a thin needle and a set of forceps to delicately extract the outermost layer of skin, known as the epidermis. The epidermis was then placed in water on a glass slide. Slide was then examined under a light microscope at a magnification of 400X. To determine the stomatal density and epidermal cells the following formula was used.

Number of stomata/mm^2 = the average number of stomata per microscopic field × the total number of microscopic field/mm^2

Number of epidermal cells/mm^2 = the Average number of epidermal cells per microscopic field × the total number of microscopic field/mm^2

Stomatal index (S.I.)

To determine the stomatal indices of specific plant species by measuring the density of stomata per given area and the density of epidermal cells per the same area (Salisbury's formula from1927) was employed. This formula allowed for the quantification of stomatal indices, which provide valuable insights into the plant's adaptation to various environmental conditions**.**

$$\mathbf{S.\ I. = S \div (S + E) \times 100}$$

Where, S.I. -: stomatal index, S- number of stomata per unit area, E- number of epidermal cells per unit area, 100- percentage proportion

Stomatal and epidermal cells size **-:** The ocular micrometer was utilized to conduct the measurements, and its calibration was achieved by comparing it to a stage micrometer under a magnification of 400X.

Anatomical Parameters

Anatomical investigations were carried out by obtaining slender vertical slices from chosen leaves, taken from both uncontaminated and contaminated locations. These slices were placed in water on a glass slide and examined under a magnification of 100X. The objective was to measure the thickness in a specific area using a standardized ocular micrometer. Twenty observations were made from each of the selected plants to represent the results.

1. Midrib region
2. Midrib adjoining region
3. The Palisade tissues
4. Spongy tissue
5. Upper epidermis
6. Lower epidermis
7. Vascular bundles

Data analysis: SAS (version 9.4) software was used for arithmetical analysis of the data.

Results

The evolution of plants biomarkers uses as a tool to monitor and evaluate the environmental state is closely linked to progress in our knowledge of molecular toxicity mechanisms of pollutants in different plant species in the ecosystem (Azzazy 2016). Air pollution control and prevention are critical for human survival, but they are also an essential first step in the development of the economy (Sneha and Sunil 2023). The air quality at the chosen sites were observed to record the impact of air pollutants on plants (Fig. 3, 4, 5). The physical characteristics, microscopic features, and internal structures of the plant samples were examined and analyzed. The findings of the air quality assessment were shown in Table 4 and the discussion was based on the analysis of different morphological, micro-morphological, and anatomical characteristics of chosen plant species from both the reference and polluted sites.

Table 4. Seasonal variations of SO2, NO2, RSPM, SPM, TSPM at study sites in Samastipur for the study period (2021-2022)

Sites	Seasons	Parameters	Minimum (µg/m3)	Maximum (µg/m3)	Average
Magardaahi ghat road in samastipure (Polluted Area)	Summer	SO_2	26.40	35.50	32.40±6.45
		NO_2	33.35	65.03	48.35±15.91
		RSPM	75.90	92.40	86.50±6.92
		SPM	103.65	123.74	130.92±11.02
		TSPM	240.15	295.75	271.12±24.69
	Monsoon	SO_2	21.90	37.27	30.09±7.16
		NO_2	25.84	40.85	34.46±7.75
		RSPM	57.78	75.99	68.62±8.65
		TSPM	135.65	175.56	150.15±25.35
		SPM	280.06	407.20	355.70±65.25
	Winter	SO_2	35.75	45.94	41.99±4.11
		NO_2	20.15	36.02	25.21±6.93
		RSPM	284.50	340.01	316.17±28.30
		SPM	142.65	175.29	115.75±25.48
		TSPM	135.65	175.58	150.11±21.35
Satmalpure Village (Non-polluted Area)	Summer	SO_2	7.89	10.99	9.29±1.57
		NO_2	10	22.51	15.56±6.37
		RSPM	79.91	91.97	87.01±6.31
		TSPM	184.55	214.90	199.98±15.18
		SPM	140.67	176.28	153.37±19.88
	Monsoon	SO_2	5.79	8.26	6.86±1.26
		NO_2	5.42	9.17	7.08±1.91
		RSPM	113.30	183.33	143.67±35.93
		TSPM	260.18	336.23	307.43±41.25
		SPM	58.78	75.96	66.68±8.65
	Winter	SO_2	11.63	15	12.73±1.2
		NO_2	19.17	35.01	27.23±7.92
		RSPM	113.30	183.33	143.67±35.93
		TSPM	152.38	197.37	174.42±22.51
		SPM	152.38	197.37	174.42±22.51

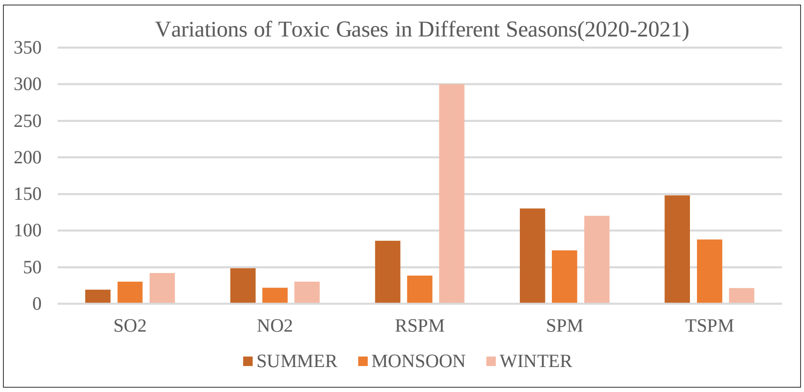

Figure 5. Graph represents variation of toxic gases in different seasons in polluted area of Magadaahi ghat road of Samastipur

The effect of pollutants on plants

Morphological Parameters

Leaf colour: The Table 5 & 6 provides information about the growth of *Mangifera indica* L. (Mango tree) across different seasons and its appearance in both polluted and non-polluted sites (Fig. 6-10). In summer and monsoon seasons, the plant appears as "Dark Green" in both polluted and non-polluted sites. However, during the winter season, it exhibits different characteristics in polluted sites, it appears as "Light Green." In non-polluted sites, it appears as "Light Green with Brown Spots."

Table 5. Leaf colour of *M. indica L.* plant species during different seasons from reference and polluted site

Plant Species	Season	Polluted site	Non- Polluted Sites
Mangifera indica L.	Summer	Dark Green	Dark green
	Monsoon	Dark green	Dark green
	Winter	Light green	Light green with Brown spots

Figure 6. Dark green leaves color of *M. indica* in Control and polluted sites in summer and Monsoon season

Figure 7. Light green leaves colour of *M. indica* in polluted sites in winter season

Figure 8. Brown spotted leaves of *Mangifera indica* L (non-polluted site)

Table 6. Morphological parameter of *M. indica* L. plant species during different seasons from reference and polluted site (Mean ± S.D.)

Morphological parameter	Season	Polluted site	Non-polluted site	Decrease (%)
Leaf Length (cm)	Summer	37.133±0.23	38.433±0.45	3.38
	Monsoon	37.6 ±0.26	36.633± 0.5	2.57
	Winter	16.533±0.611	16.233 ±0.49	1.81
Leaf Breadth(cm)	Summer	21.5 ±0.56	20.767±0.40	3.41
	Monsoon	21.5 ±0.56	20.767±0.40	3.41
	Winter	20.633±0.90	19.933±0.60	3.39
Leaf Area	Summer	95.667 ±3.05	100.67±6.03	4.97
	Monsoon	100.33 ±4.04	108.33±8.02	7.38
	Winter	93.67 ±2.52	98.667±2.52	5.07
Petiole Length	Summer	12.467 ± 0.15^{Ay}	12.967 ± 0.15^{Ax}	3.86
	Monsoon	13.333 ± 0.40^{B}	13.867 ± 0.15^{B}	3.85
	Winter	11.267 ± 0.25^{Cy}	12.033 ± 0.35^{Cx}	6.37
Micro-Morphological Parameters				
Stomatal Width	Summer	13.9 ± 2.40^{y}	16.68 ± 0.00^{x}	16.67
	Monsoon	16.68±0.00	18.07 ±2.41	7.69
	Winter	11.12 ± 2.41^{y}	12.51 ± 0.00^{x}	11.11
Stomatal size	Summer	231.85 ± 0.00^{Ay}	324.59 ± 0.00^{Ax}	28.57
	Monsoon	276.29 ± 5.79^{Ax}	121.72 ± 0.00^{Ay}	55.94
	Winter	328.46 ± 5.80^{Bx}	200.94 ± 5.80^{By}	38.82
Stomatal number (per mm^2)	Summer	33 ± 3^{Ay}	39 ± 3^{ABx}	15.38
	Monsoon	38 ± 1.73^{B}	40 ± 1.73^{B}	5.00
	Winter	48 ± 6^{Bx}	31 ± 4.58^{Ay}	35.42
Epidermal cell length	Summer	18.21 ± 0.24^{Ay}	19.04 ± 0.24^{Ax}	4.38
	Monsoon	19.32 ± 0.24^{A}	18.90 ± 0.24^{B}	2.16
	Winter	26.41 ± 0.87^{ABy}	29.05 ± 0.64^{x}	9.09
Epidermal cell width	Summer	12.51 ± 0.00^{y}	16.68 ± 0.00^{x}	25.00
	Monsoon	15.29 ±2.41	18.07 ±2.41	15.38
	Winter	12.51 ± 0.00^{y}	18.07 ± 2.41^{x}	30.77
Epidermal cell size	Summer	16.68 ± 0.00^{Ay}	19.46 ± 2.41^{x}	14.29
	Monsoon	227.79 ± 0.00^{Ay}	317.64 ± 0.00^{ABx}	28.28
	Winter	224.32 ± 0.00^{A}	258.90±1.53	13.36
Epidermal cell number (per mm2)	Summer	79 ± 4.58^{Ay}	115 ± 21.07^{Ax}	31.30
	Monsoon	35 ± 2.65^{B}	104 ± 10.54^{A}	10.58
	Winter	56 ± 7.55^{Ay}	$72 \pm 6B^{x}$	22.22
Stomatal index value	Summer	29.48 ± 2.79^{A}	25.58± 2.84	-15.27*
	Monsoon	22.82 ± 2.31^{AB}	22.30 ±1.26	-2.30*
	Winter	26.59 ± 2.79^{B}	25.36±0.63	-4.83*

***Values bearing different superscripts in small alphabets across the columns (x, y, z) differ significantly ($p \leq 0.05$) and depict variations between reference and polluted site.
Values bearing different superscript in capital alphabets (A, B, C) down the row differ significantly ($p \leq 0.05$) and depict variations among summer, monsoon and winter seasons.
Decrease (%) was calculated as: {(Reference site value- Polluted site value)/ Reference site value} ×100
Values bearing different superscripts in small alphabets across the columns (x, y, and z) differ significantly ($p \leq 0.05$) and depict variations between reference and polluted site.
Value in asterisk indicate increase in the value of stomatal index in (%)

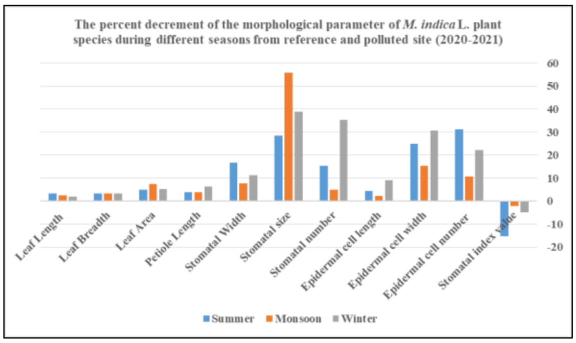

Figure 9. Graph shows the percent decrement of all morphological parameter of *M. indica* L. tree from all seasons of the year (2021-2022)

Figure 10. Shows the length of leaves taken from the Magardaahi ghat road (polluted Area)

Anatomical parameters

Table 7. Anatomical features of *M. indica L*. during different seasons from reference and polluted site (Mean ± S.D.)

Anatomical parameter	Season	Polluted site	Non- polluted site	Decrease (%)
Midrib region	Summer	1344±0.00^{Ay}	1354.67±9.23^{Ax}	0.79
	Monsoon	1370.67±9.24^{Ax}	1354.67±9.23^{Ay}	1.17
	Winter	1317.33±9.23^{By}	1338.67 ±9.23^{Bx}	1.59
Midrib adjoining region	Summer	352±0.00^{Ay}	362.67±9.23^{Ax}	2.94
	Monsoon	1338.67±9.23^{Bx}	1317.33 ±9.23^{By}	1.59
	Winter	325.33±9.24^{Cy}	346.67±9.24^{Cx}	6.15
The Palisade tissue thickness	Summer	117.33±9.23^{Ay}	133.33±9.23^{Ax}	12.00
	Monsoon	133.33±9.24^{By}	144±0.00^{Ax}	7.41
	Winter	106.67±9.23^{Ay}	128±0.00^{Bx}	16.67
Spongy tissue	Summer	197.33±9.2^{Ay}	218.67± 9.23^{Ax}	9.76
	Monsoon	234.67±9.24^{By}	250.67 ±9.24^{Bx}	6.38
	Winter	170.67±9.23^{Cy}	181.33 ±9.2^{Cx}	5.88
Upper epidermis	Summer	197.33±93.23^{Ay}	208±0.00^{Ax}	5.13
	Monsoon	170.67 ±9.23^{Cy}	192±0.00^{Cx}	11.11
	Winter	117.33 ±9.23^{B}	138.67±9.24^{B}	15.38
Lower epidermis	Summer	245.33±9.24^{Ay}	256±0.00^{Ax}	4.17
	Monsoon	250.67 ±9.23^{Ay}	266.67±9.23^{Bx}	6.00
	Winter	202.67±18.47^{By}	234.67±9.24^{Cx}	13.64
Vascular bundles	Summer	522.67 ±9.23^{Ay}	549.33± 9.23^{Ax}	4.85
	Monsoon	565.33 ±9.2^{By}	586.67 ±9.2^{Bx}	3.64
	Winter	490.67 ±9.23^{Cy}	538.67±9.24^{Ax}	8.91

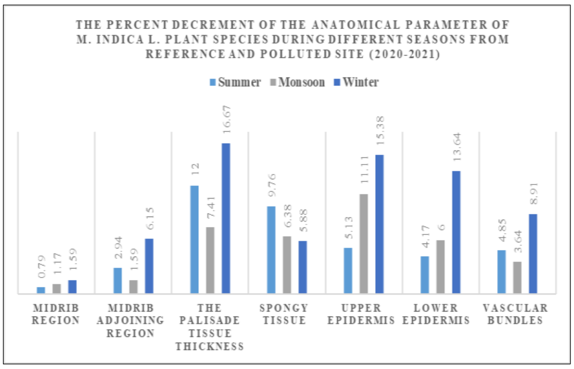

Figure 11. Graph shows the percent decrement of all anatomical parameter of *M. indica* L. tree from all seasons of the year (2021-2022)

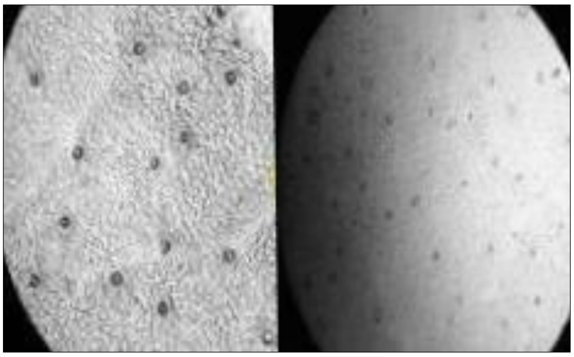

Figure 12. The leaf structure of Mangifera indica from the polluted region, under Light Microscope exhibits abnormal stomatal shapes or irregular stomatal structures. In contrast, the leaves from the unpolluted area display normal stomatal features.

Discussion

The Table 4 provides air quality data for two different locations, Magardaahi Ghat Road in Samastipur (a polluted area) and Satmalpure Village (a non-polluted area), for different seasons (summer, Monsoon, and winter) and various air quality parameters (SO_2, NO_2, RSPM, SPM, and TSPM). The parameters are measured in micrograms per cubic meter, and the table presents the minimum, maximum, and average values for each parameter in each season for both locations. At Polluted Area (Magardaahi Ghat Road) in summer SO_2 levels range from a minimum of 26.40 µg/m³ to a maximum of 35.50 µg/m³, with an average of 32.40 µg/m³. NO_2 levels range from a minimum of 33.35 µg/m³ to a maximum of 65.03 µg/m³, with an average of 48.35 µg/m³. RSPM levels range from a minimum of 75.90 µg/m³ to a maximum of 92.40 µg/m³, with an average of 86.50 µg/m³. SPM levels range from a minimum of 103.65 µg/m³ to a maximum of 123.74 µg/m³, with an average of 130.92 µg/m³.

TSPM levels range from a minimum of 240.15 µg/m³ to a maximum of 295.75 µg/m³, with an average of 271.12 µg/m³. In Monsoon, SO_2 levels range from a minimum of 21.90 µg/m³ to a maximum of 37.27 µg/m³, with an average of 30.09 µg/m³. NO_2 levels range from a minimum of 25.84 µg/m³ to a maximum of 40.85 µg/m³, with an average of 34.46 µg/m³. RSPM levels range from a minimum of 57.78 µg/m³ to a maximum of 75.99 µg/m³, with an average of 68.62 µg/m³. SPM levels range from a minimum of 280.06 µg/m³ to a maximum of 407.20 µg/m³, with an average of 355.70 µg/m³. TSPM levels range from a minimum of 135.65 µg/m³ to a maximum of 175.56 µg/m³, with an average of 150.15 µg/m³. In winter, SO_2 levels range from a minimum of 35.75 µg/m³ to a maximum of 45.94 µg/m³, with an average of 41.99 µg/m³. NO_2 levels range from a minimum of 20.15 µg/m³ to a maximum of 36.02 µg/m³, with an average of 25.21 µg/m³. RSPM levels range from a minimum of 284.50 µg/m³ to a maximum of 340.01 µg/m³, with an average of 316.17 µg/m³. SPM levels range from a minimum of 142.65 µg/m³ to a maximum of 175.29 µg/m³, with an average of 115.75 µg/m³. TSPM levels range from a minimum of 135.65 µg/m³ to a maximum of 175.58 µg/m³, with an average of 150.11 µg/m³. At Non-polluted Area of Satmalpure Village, In Summer, SO_2 levels range from a minimum of 7.89 µg/m³ to a maximum of 10.99 µg/m³, with an average of 9.29 µg/m³, NO_2 levels range from a minimum of 10 µg/m³ to a maximum of 22.51 µg/m³, with an average of 15.56 µg/m³. RSPM levels range from a minimum of 79.91 µg/m³ to a maximum of 91.97 µg/m³, with an average of 87.01 µg/m³. TSPM levels range from a minimum of 184.55 µg/m³ to a maximum of 214.90 µg/m³, with an average of 199.98 µg/m³. SPM levels range from a minimum of 140.67 µg/m³ to a maximum of 176.28 µg/m³, with an average of 153.37 µg/m³. In Monsoon, SO_2 levels range from a minimum of 5.79 µg/m³ to a maximum of 8.26 µg/m³, with an average of 6.86 µg/m³. NO_2 levels range from a minimum of 5.42 µg/m³ to a maximum of 9.17 µg/m³, with an average of 7.08 µg/m³. RSPM levels range from a minimum of 113.30 µg/m³ to a maximum of 183.33 µg/m³, with an average of 143.67 µg/m³. TSPM levels range from a minimum of 260.18 µg/m³ to a maximum of 336.23 µg/m³, with an average of 307.43 µg/m³. SPM levels range from a minimum of 58.78 µg/m³ to a maximum of 75.96 µg/m³, with an average of 66.68 µg/m³. In winter, SO_2 levels range from a minimum of 11.63 µg/m³ to a maximum of 15.00 µg/m³, with an average of 12.73 µg/m³, In NO_2 levels range from a minimum of 19.17 µg/m³ to a maximum of 35.01 µg/m³, with an average of 27.23 µg/m³. RSPM levels range from a minimum of 113.30 µg/m³ to a maximum of 183.33 µg/m³, with an average of 143.67 µg/m³.

TSPM levels range from a minimum of 152.38 µg/m³ to a maximum of 197.37 µg/m³, with an average of 174.42 µg/m³. SPM levels range from a minimum of 152.38 µg/m³ to a maximum of 197.37 µg/m³, with an average of 174.42 µg/m³. These values represent the air quality in the specified areas and seasons, with higher values indicating more pollution in the air. Air pollution has increased tremendously that is affecting the proper growth of plants in its vicinity. The rapid addition of toxic substances to environment is responsible for altering the ecosystem. Plants growing in heavy trafficular area are thus exposed to variety of pollutants such as SMP, RSMP, NOx, & SO_2 etc. (Giri et al 2013). Leaf is the most sensitive part to be affected by air pollutants instead of all other plant parts such as stem and roots. The sensitivity rests on the fact that the major portions of the important physiological processes are concerned with leaf. Therefore, the leaf at its various stages of development, serves as a good indicator to air pollutants. Pollutants came from the auto emission can directly affect the plant by entering in to the leaf, destroying individual cells, and reducing the plant ability to produce food (Lighari and Zaidi 2013). The Table 6, presents morphological and micro-morphological parameters of a plant, measured during different seasons in both polluted and non-polluted sites. In morphological Parameters the length of leaves was measured in centimeters during summer, monsoon, and winter. In the polluted site, leaf length decreased by 3.38% in summer, 2.57% in monsoon, and 1.81% in winter compared to the non-polluted site. Leaf breadth was measured in centimeters during the same seasons. It showed a decrease of 3.41% in both summer and monsoon, and 3.39% in winter in the polluted site compared to the non-polluted site. Leaf area was measured in square centimeters during the seasons. In the polluted site, leaf area decreased by 4.97% in summer, increased by 7.38% in monsoon, and decreased by 5.07% in winter compared to the non-polluted site. Petiole length was measured in centimeters during the seasons. In the polluted site, it decreased by 3.86% in summer, 3.85% in monsoon, and 6.37% in winter compared to the non-polluted site. In Micro-Morphological Parameters stomatal width was measured in micrometers. In the polluted site, it decreased by 16.67% in summer, increased by 7.69% in monsoon, and decreased by 11.11% in winter compared to the non-polluted site. Stomatal size was measured in square micrometers. In the polluted site, it increased by 28.57% in summer, decreased by 55.94% in monsoon, and increased by 38.82% in winter compared to the non-polluted site. Stomatal density was measured per square millimeter. In the polluted site, it increased by 15.38% in summer, 5.00% in monsoon, and decreased by 35.42% in winter compared to the non-polluted site. Epidermal cell length was measured in micrometers. In the polluted site, it increased by 4.38% in summer, decreased by 2.16% in monsoon, and increased by 9.09% in winter compared to the non-polluted site. Epidermal cell width was measured in micrometers. In the polluted site, it increased by 25.00% in summer, 15.38% in monsoon, and 30.77% in winter compared to the non-polluted site. Epidermal cell size was measured in square micrometers. In the polluted site, it increased by 14.29% in summer, 28.28% in monsoon, and 13.36% in winter compared to the non-polluted site. Epidermal cell density was measured per square millimeter. In the polluted site, it increased by 31.30% in summer, decreased by 10.58% in monsoon, and increased by 22.22% in winter compared to the non-polluted site. Stomatal index value represents the ratio of stomata to epidermal cells. It decreased by 15.27% in summer, 2.30% in monsoon, and 4.83% in winter in the polluted site compared to the non-polluted site. In summary, these parameters provide detailed insights into how the plant's morphology and micro-morphology vary in different seasons and between polluted and non-polluted environments. The growth of plant species collected from uncontaminated sites is superior in terms of their morphological parameters compared to those collected from contaminated sites. Plants can hinder their growth due to their capacity to absorb, retain, and incorporate pollutants on their leaves. The toxic gases emitted by vehicles can combine with pollen grains from different plant species. These interactions conduct changes in the ontogeny, physiology and morphology in pollen grains of a plant. Alterations in chemical compounds of protein bring changes in the nature of biochemical and morphological structure of pollen grains and effect badly in its amino acids and flavonoids (Naira and Anzer 2022). Table 7 represent the changes in various anatomical parameters of plant leaves in different seasons and between polluted and non-polluted sites, along with the percentage decrease in each case. The midrib region thickness varies seasonally, with a slight decrease in summer (0.79%), an increase in Monsoon (1.17%), and a larger increase in winter (1.59%). This region exhibits a thickness increase in summer (2.94%), a slight increase in Monsoon (1.59%), and a significant increase in winter (6.15%). Palisade tissue thickness increases in summer (12.00%), decreases in Monsoon (7.41%), and decreases further in winter (16.67%). The thickness of spongy tissue increases in summer (9.76%), Monsoon (6.38%), and winter (5.88%). The upper epidermis thickness increases in summer (5.13%), significantly increases in Monsoon (11.11%), and even more in winter (15.38%). The lower epidermis thickness increases in summer (4.17%), Monsoon (6.00%), and winter (13.64%). Vascular bundles increase in summer (4.85%), Monsoon (3.64%), and winter (8.91%). Overall, these findings suggest that seasonal variations and pollution levels impact the anatomical parameters of the plant leaves, with some parameters showing increases while others decrease under different conditions. Study highlights the detrimental impact of automobile emissions on the physical characteristics and structure of *M. indica* trees obtained from both polluted and unpolluted regions within the Samastipur district. So, it is suggested that to promote afforestation and reforestation initiatives within the city and its surroundings. There should be a heightened focus on developing green belts along highways and roads. It's crucial to closely monitor the condition of vehicles on the road, especially older and poorly maintained ones, as they contribute significantly to pollution in the surrounding environment. Increasing public awareness about these eco-friendly practices is essential.

Conclusion

Present study revealed the concentration of all the air quality parameters viz. SO2, NO2, RSPM and SPM to be higher at the polluted site of magardaahi ghat than the reference site of the satamalpure village area in all the seasons for the one years of the study period. The presence of air pollution negatively impacted all the parameters studied in plants at the polluted site, leading to a decrease in values for both morphological and anatomical characteristics compared to those at the non-polluted site. Based on the findings, it is clear that the roads in Samastipure district require regular maintenance. Issues like encroachments, potholes, and narrow roads contribute to increased fuel consumption and, subsequently, higher pollution levels. Rapid deterioration of ambient air quality has been witnessed over the years due to economic growth, higher industrialization and consistent population rise. Automobile emissions contribute about 57-75% of total emissions in urban areas **(**Pourkhabbaz et al. 2010). Constant awareness and enforcement drives should be conducted for the people to follow the traffic rules. Encouraging afforestation and reforestation initiatives within and around the city is recommended. It's essential to prioritize the development of green belts along highways and roads. Monitoring the condition of vehicles on the road is crucial because old and poorly maintained vehicles contribute to increased pollution in the surrounding environment. Promoting awareness about these environmentally friendly practices among the general public is also essential.

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