



# Assessment of the Impact of Air Pollutants on the Photosynthetic Pigments of Litchi Plants in Dehradun City, Uttarakhand

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## ABSTRACT

Air pollution has indeed become one of the most significant concerns worldwide. Vehicular emissions are among the most outstanding sectors emitting many pollutants into the atmosphere. It is affecting human health and causing significant damage to plants. A comprehensive study of the effects of air pollution on plant physiology is required because of the growing danger it poses to ecosystems and human health. This research in Dehradun City, Uttarakhand, aims to evaluate the impact of air pollution on the photosynthetic pigments of Litchi plants (*Litchi chinensis*). The main focus of this research is to understand how common air pollutants, such as sulfur dioxide, nitrogen dioxide, and particulate matter, affect photosynthetic pigments (carotenoids and chlorophylls). Understanding the connection between plant health and air quality is crucial for promoting a healthy ecological balance in urban areas. This paper depicts the condition of the litchi plant in Dehradun City due to air pollution. We monitored Rajpur Road, ISBT, and one at the control site, i.e., Graphic Era Deemed University. The particulate matter (PM<sub>10</sub>), SO<sub>x</sub>, and NO<sub>x</sub> were observed to be high at ISBT, 148.34±31.39 µg.m<sup>-3</sup>, 12.96±5.79 ppm, 23.99±2.04 ppm, respectively, and lowest at the control site, 95.30±3.38µg.m<sup>-3</sup>, 9.87±1.70 ppm, 10.92±1.40 ppm, respectively. For the plant analysis, chlorophyll a, chlorophyll b, total chlorophyll content, and carotenoids were calculated. This study will shed light on the complex interplay between air quality and Litchi plant photosynthetic performance, which in turn informs solutions for environmentally responsible management.

## INTRODUCTION

Rising air pollution levels can be attributed to several factors, including rapid industrialization, unchallenged urbanization, an alarming increase in vehicles on the road, rapid population growth, and a lack of foresight in the city's future development plan (Madan & Verma 2015). Industrialization causes significant pollution and environmental issues along with progress. Dust is a major cause of illness in humans and other animals due to its presence in ambient air from industrial sources. Up to 35% of India's air pollution is made up of dust. Industries such as coal mining, coal-fired electricity generation, road transportation, cement manufacture, and stone crushing generate significant amounts of airborne dust (Shukla et al. 2019). Particulate matter is a substantial air pollutant from a combination of natural and artificial sources. The structure of particulate matter contained several different heavy metals. One of the principal air pollutants with significant adverse effects on health and the economy is these heavy metals, primarily released by moving cars (Nabizadeh et al. 2018). In today's highly populated and extensively travelled cities, urban air is. Pollution has emerged as a major environmental concern that cannot be overlooked throughout development (Ding et al. 2023). Increased hospitalisation rates and the development of respiratory illnesses like chronic obstructive pulmonary disease and asthma have been linked to even low levels of air pollution exposure. Asthma, pulmonary insufficiency, cardiovascular

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disease, and death from cardiovascular causes are all worsened by prolonged exposure to air pollution. There is also mounting evidence that air pollution adversely affects human health in early life, such as respiratory, cardiovascular, mental, and prenatal disorders that can lead to either infant mortality or chronic disease in later years (Manisalidis et al. 2020). Environment-related factors impact health and human capital creation, which are major production determinants and partially determine economic success. Many high-income nations' strategies emphasize sustainable growth via limiting environmental impact. However, fast economic expansion in many middle- and low-income nations has kept environmental conditions affecting the community (Merkus 2024).

The devastating effects of air pollution on ecosystems and human health have made their alarming rise in recent years an issue of international concern. Even the lovely Uttarakhand area, where the city of Dehradun is located, is not safe from this problem. Air quality in the area has been declining due to a combination of factors, including fast urbanisation, industrialization, and emissions from vehicles. A fruit-bearing tree that is commercially and ecologically important in the area, the Litchi plant (*Litchi chinensis*) is one of the susceptible species that will be impacted by this change in the environment. A photo of the litchi plant at the control site is shown in Fig. 1.

To put it simply, the photosynthetic process is crucial to the well-being and growth of plants as a whole. An essential part of this process is the absorption of light energy by photosynthetic pigments like carotenoids and chlorophylls, which allow for the conversion of carbon dioxide into organic molecules. Nevertheless, there has been little investigation into the harmful impacts of air pollution on these vital pigments, especially as they pertain to Litchi plants in Dehradun.

Like many other developing countries, India has seen its air quality steadily decline over the past two decades. Air pollution is a growing problem worldwide, especially in major metropolitan areas of developing countries. An increasing number of vehicles, an increasingly urban population, unfriendly fuels, poorly maintained roads, and a lack of stringent environmental legislation contribute to India's rapidly worsening urban air pollution (Chauhan & Joshi 2021). Plants have been used as biomarkers that help us understand air quality. Biomarkers are fluctuations in plant properties that provide swift insight into the environmental quality of a location at a specific moment. The leaves of plants exhibit the most pronounced responses to various environmental conditions (Mukherjee et al. 2019).

Trees in cities help clean the air by acting as a sponge for harmful gases and particles. Plants also act as scavengers, removing contaminants from the air we breathe. The level of

tolerance or sensitivity of the plants to particulate pollution typically determines the nature and impact of the particulate problem (Rai & Panda 2014). Sulphur can get into plants through their roots as the sulphate ion, their stomata as the gaseous SO<sub>2</sub>, or by dissolving as the sulphite ion in water. Plants can utilise both kinds through normal sulphate metabolism. The number of these ions that is over normal levels is the amount that is detrimental to plant metabolism. Sulphur dioxide is the most prevalent air pollutant that can adversely affect vegetation. Sulphur is a crucial component of plants' proteins, vitamins, and amino acids, making it crucial for their general metabolism (Malhotra & Hocking 1976).

### Status of Litchi Cultivation in India

The Litchi (*Litchi chinensis* Sonn.), often known as the "Queen of Fruits," is a member of the Sapindaceae family. The litchi tree is said to have originated in the region between South China and North Vietnam around 1500 BC; however, now it may be found all over the world (Sahni et al. 2020). Around 300 years ago, the Kingdom of Tripura in India brought the litchi to Bengal and Assam, and by the end of the 17th century, the litchi had made its way to Burma. Initially confined to Bengal, the production quickly made its way across India and across the remaining parts of the tropics and subtropics (Nath et al. 2022). The litchi tree is extremely delicate and susceptible to environmental changes. It thrives in temperatures between 13 and 32 degrees north latitude and 6 and 29 degrees south latitude. Short, dry winters with temperatures of 15°C or below are ideal, but lengthy, hot summers are beneficial for optimal growth and blooming. This is why it can only be grown in a few nations. Litchi is only grown commercially in the northern Indian states of Tripura, Jammu and Kashmir, and the Gangetic plains, near the foothills of the Himalayas. Litchi is only harvested from May to June in northern India, while it is harvested in December and January in southern India; therefore, the fruit is always accessible. Litchi (*Litchi chinensis* Sonn.) is a



Fig. 1: The litchi plant at the controlled site.

subtropical fruit with a short shelf life and is rich in ascorbic acid, vitamin C, and protein and fat. Among the other fruit families, the litchi fruit is the most loved fruit consumed by people worldwide, belongs to the family Sapindaceae, and grows in the tropical and subtropical regions of the earth (Nath et al. 2016). This research paper aimed to identify the quality of litchi plants in three different areas concerning air pollution. A fruit tree with a strong mycorrhizal relationship, litchi (*Litchi chinensis* Sonn.), is among the most significant members of the Sapindaceae family (Lal et al. 2017a, Lal et al. 2020a, Nath et al. 2022). Cultivation is likely limited to a few nations and states (North and Eastern India included) because of the plant's extreme sensitivity to temperature extremes, especially during the flower bud differentiation process (Lal et al. 2017a, Nath et al. 2022). After China, India is the world's second-largest litchi producer. When it comes to producing high-quality litchi in India, Bihar takes the lead. Litchi offers both on-farm and off-farm jobs, which means it supports millions of people in this state. When temperatures are high, the fruiting body panicles emerge more quickly, but when temperatures are low, the panicles emerge more slowly (Lal et al. 2018, Lal et al. 2019a, Nath et al. 2022). Selection of better cultivars in litchi should prioritise length and girth of panicle for genetic improvement (Lal et al. 2020b). There are both internal and extrinsic elements that might induce blooming. The success of fruit set in litchi relies on the sources of pollen grains, and a higher phenol content increases flowering (Purbey et al. 2019). According to Lal et al. (2019b), temperature and crop load have a significant impact on fruit retention, yield, and quality. In order to maximise fruit weight, it is best to minimise fruit burden (Lal et al. 2017b, Nath et al. 2022). According to Pandey et al. (2018), litchi is an excellent food source of sugar, ascorbic acid, flavonoids, and phenolic compounds.

### **The Research Problem**

Determining how air pollution affects the photosynthetic pigments of Litchi plants in Dehradun City is the main focus of this study's research challenge. We need to know how much of an impact contaminants like sulphur dioxide, particulate matter, and nitrogen dioxide have on the makeup and operation of these pigments. The study topic also includes determining if the Litchi plants show adaptive responses or die out when exposed to air pollution.

### **Significance of the Study**

On several fronts, this study is quite significant. In the first place, the results should help us understand the physiological mechanisms by which Litchi plants react to environmental stress by illuminating the complex link between air quality and photosynthetic activity. In order to protect the well-being

and productivity of these economically significant plants, this information is crucial for developing efficient mitigation solutions. Public health and environmental management are two more areas that could benefit from the study's findings. Finding out how Litchi plants react to air pollution can help us understand the interplay between plant health, air quality, and environmental health as a whole. Policymakers and urban planners may use these findings to their advantage when coming up with long-term plans to reduce air pollution and promote a more sustainable ecological balance in cities. Presenting a thorough investigation of the topic with implications for environmental preservation and human well-being, this study aims to fill important knowledge gaps on the effects of air pollutants on the photosynthetic pigments of Litchi plants in Dehradun.

## **MATERIALS AND METHODS**

### **Study Area**

The Doon Valley, where the majority of Dehradun is situated, ranges in elevation from 410 metres (1,350 feet) at Clement Town to over 700 metres (2,300 feet) at Malsi, which is 15 kilometres (9.3 miles) distant (Fig. 2). Despite this, there are 450 metres of average height above sea level (1,480 ft). The Lesser Himalayan Range begins in Malsi and continues to Mussoorie and beyond. The sacred Ganga River is to the east of the Doon Valley, and the Yamuna River is to the west. The Himalayas can be found to the north, and the Shivalik range to the south. Dehradun's northern and southern boundaries are provided by the Sal Woods and the Himalayas, respectively, while the Song and Tons rivers form its eastern and western boundaries. Doon Valley is the confluence of two of India's major rivers. In particular, the Yamuna and Ganges rivers meander through some breathtaking landscapes. Popular Himalayan tourist destinations like Mussoorie, Dhanaulti, Chakrata, New Tehri, Uttarkashi, Harsil, and Chopta-Tungnath are conveniently located nearby. Dodital's Valley of Flowers, Dayara Bugyal, Kedarkantha, Har Ki Dun, and Hemkund Sahib are all within driving distance, as are other popular summer and winter hiking destinations. The closest major city, Dehradun, is usually used to travel to the Hindu holy cities of Haridwar and Rishikesh and the Chota Char Dham Himalayan pilgrimage circuit, including Yamunotri, Gangotri, Kedarnath, and Badrinath.

### **Study Sites**

The two famous places, i.e., ISBT and Rajpur Road of Dehradun, were chosen, including the controlled site, i.e., Graphic Era Deemed to be University, as the study sites. The sample was collected from the litchi plant present roadside. The study period includes data from one year. These areas

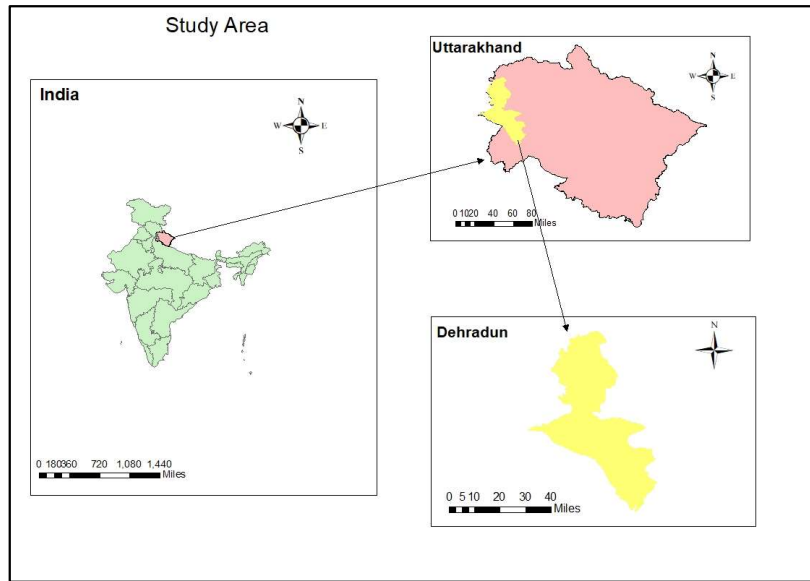


Fig. 2: The location map of the study area.

are designed to serve the state's residential, commercial, and industrial zones. Three locations were chosen in Dehradun, and they are as follows: the ISBT and Rajpur Road (Fig. 3). These areas were regarded as the city's most densely populated and heavily travelled thoroughfares at the time. ISBT stands for the Interstate Bus Terminal and is an interstate bus terminal from which buses leave for various destinations, and arrivals of buses from various states, together with a large number of passengers, take place.

Both locations have a substantial volume of traffic, which may include Vikram cars, city buses, two-wheelers, and four-wheelers. Despite this, the road known as Rajpur is the one that sees the highest traffic because it is the connection between Dehradun and Mussoorie. Graphic Era Deemed to Be University, Dehradun, was chosen as the controlled site because of its locality in the cantonment area with lush green forest at its backside and the lowest interference of vehicles.

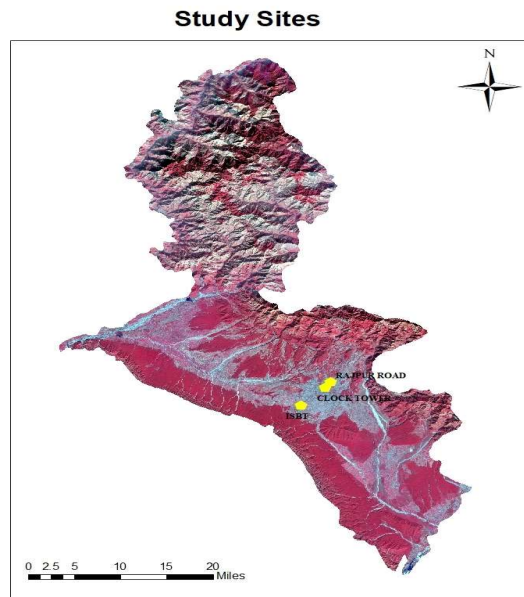


Fig. 3: Dehradun city map showing three selected sites.

## Sample Collection

The chosen plant's leaves were carefully collected from each site and stored in plastic bags, and immediate analysis was done after reaching the laboratory. Samples of leaves were taken from both polluted and unpolluted areas. The mature plants ranged in height from about five to eight feet above the ground. Maclachlan & Zalik's (1963) method was considered a standard method for analysing chlorophyll and carotenoid content in the leaf samples.

## Determination of Photosynthetic Pigments

The photosynthetic pigments include chlorophyll a, chlorophyll b, total chlorophyll content, and carotenoid content. In photosynthetic organisms, such as plants and green growth, carotenoids play an essential role and protect chlorophyll from photooxidative damage. Carotenoids are a kind of pigment that dissolves in fat (Britton 1995). Since chlorophyll is an essential part of plant metabolism and a drop in chlorophyll content is associated with stunted plant development, measuring chlorophyll content can help determine how much air pollution is affecting plants. Chlorophyll is the principal photoreceptor in photosynthesis, the process wherein light causes carbon dioxide to be "settled" to create carbohydrates and oxygen. The physiological status of the plants may be inferred from the chlorophyll and carotenoids found in their leaves in this way. The moment chlorophyll levels decrease, plant productivity declines, and the plant's health becomes apparent. Thus, plant tolerance is defined as the capacity to sustain chlorophyll levels despite exposure to polluted environments (Uka et al. 2017). Chlorophyll by using Maclachlan & Zalik's (1963) method. In a pestle and mortar with ice, about 1g of leaves were homogenised with 4 mL of 80% acetone. This slurry was centrifuged at 4°C for 20 min at a speed of 13000 rpm. The filtrate was then analysed for absorbance by a UV spectrophotometer at 645 nm and 663 nm after filtering.

$$\text{Chlorophyll } a = \frac{(12.3 D_{663} - 0.86 D_{645})V}{d \times 1000 \times W}$$

$$\text{Chlorophyll } b = \frac{19.3 D_{645} - 3.6 D_{663}}{d \times 1000 \times W}$$

Total chlorophyll content = chlorophyll a + chlorophyll b

Carotenoid content was determined following the method described by Duxbury & Yentsch (1956). The filtrate obtained during chlorophyll estimation was subsequently utilized for carotenoid analysis. Absorbance readings were recorded at wavelengths of 480 nm and 510 nm to determine carotenoid concentration. The calculation was performed using the following formula:

$$\text{Carotenoids content} = [0.304 (\text{absorbance}_{450}) - 0.0596 (\text{absorbance}_{510})]$$

## Determination of Air Pollutants

The analysis of air pollutants was done by using the respirable dust sampler (Model no. Envirotech APM 460), and gaseous pollutants were observed by using the gaseous assembly (Model no. APM 433). Air pollution analysis was done using the Central Pollution Control Board (CPCB) method. The Jacob & Hochheiser (1958) method is used for the analysis of nitrogen dioxide, whereas the West & Gaeke (1956) method was used for the analysis of sulphur dioxide.

## Statistical Analysis

The study period includes data for 1 year from March 22 to February 23. Each experiment was repeated five times, and the average and standard deviation of each set of results were presented. Along with that, a Pearson's correlation test was also performed for each air pollutant with photosynthetic pigments at each site.

## RESULTS AND DISCUSSION

### Variation in PM<sub>10</sub>, SO<sub>x</sub> and NO<sub>x</sub> Concentration at Different Sites

This segment will explain the particulate matter, sulphur dioxide and nitrogen dioxide concentration of one year (Tables 1, 2 and 3; Fig. 4) where we found the mean value at Raipur road to be  $138.44 \pm 26.82 \mu\text{g.m}^{-3}$  and at ISBT, it was  $148.34 \pm 31.39 \mu\text{g.m}^{-3}$ , while at the control site, it was  $95.30 \pm 3.38 \mu\text{g.m}^{-3}$ . On the other hand, the concentration of SO<sub>x</sub> was  $16.57 \pm 2.66$  ppm at Rajpur Road,  $12.96 \pm 5.79$  ppm at ISBT and  $9.87 \pm 1.70$  ppm at the controlled site. The NO<sub>x</sub> concentration was  $21.26 \pm 3.68$  ppm at Rajpur road,  $23.99 \pm 2.04$  ppm, and  $10.92 \pm 1.40$  ppm at the controlled site (Tables 4 & 5). Another observation was made based on seasonal variations, in which we observed that the highest particulate matter concentration was noticed in the summer period at  $174.81 \pm 12.36 \mu\text{g.m}^{-3}$  at ISBT, and the lowest was observed in the monsoon month at  $115.38 \pm 20.98 \mu\text{g.m}^{-3}$  (Table 2).

Sulphur dioxide (SO<sub>x</sub>) concentration was high at ISBT in the winter months,  $20.80 \pm 3.46$  ppm and the lowest was noticed in the monsoon month at the controlled site,  $8.55 \pm 0.91$  ppm (Table 3). Nitrogen dioxide (NO<sub>x</sub>) concentrations were found to be highest at ISBT in the summer months, i.e.,  $25.93 \pm 0.27$  ppm and the lowest were found at the controlled site in the monsoon months, i.e.,  $9.66 \pm 0.61$  ppm. In the above observations, the summer season includes March to June, the monsoon season includes July to October, and the winter season includes November to February.

Table 1: Monthly variation in pollutants at Rajpur Road.

	Summer	Monsoon	Winter
PM <sub>10</sub>	164.51±5.64	110.31±10.73	153.21±17.95
SO <sub>x</sub>	19.87±0.55	14.86±2.54	20.54±5.06
NO <sub>x</sub>	25.06±0.91	20.54±5.06	19.26±0.60

\*Mean ± standard deviation

Table 2: Monthly variation in pollutants at ISBT.

	Summer	Monsoon	Winter
PM <sub>10</sub>	174.81 ± 12.36	115.38 ± 20.98	171.37 ± 15.93
SO <sub>x</sub>	22.56 ± 0.21	19.82 ± 1.11	20.80 ± 3.46
NO <sub>x</sub>	25.93 ± 0.27	23.57 ± 2.54	22.71 ± 1.37

\*Mean ± standard deviation

Table 3: Monthly variation in pollutants at the control site.

	Summer	Monsoon	Winter
PM <sub>10</sub>	96.02±1.72	95.47±5.52	94.42±2.59
SO <sub>x</sub>	11.70±1.33	8.55±0.91	9.86±1.08
NO <sub>x</sub>	12.37±0.86	9.66±0.61	11.07±1.07

\*Mean ± standard deviation

The concentration of pollutants was also studied by Deep et al. (2019) from 2011 to 2014, where they observed that the

Table 4: Comparative annual variation in pollutants at Rajpur Road and the Controlled site.

	P	NP	%R
PM <sub>10</sub>	138.44±26.82	95.30±3.38	45%
SO <sub>x</sub>	16.57±2.66	9.87±1.70	68%
NO <sub>x</sub>	21.26±3.68	11.2±1.58	95%

\*P- polluted, NP- Non-polluted, %R- percentage reduction

Table 5: Comparative annual variation in pollutants at ISBT and the control site.

	P	NP	%R
PM <sub>10</sub>	148.34±31.39	95.30±3.38	55%
SO <sub>x</sub>	12.96±5.79	9.87±1.70	31%
NO <sub>x</sub>	23.99±2.04	10.92±1.40	23%

\*P- polluted, NP- Non-polluted, %R- percentage reduction

year 2014 was highly polluted in comparison to others, and pollutant concentration was minimum during the monsoon period. Similarly, (Sharma et al. 2017) studied the effects of the pollutant on human health, where they observed pollutants like carbon monoxide (CO), sulphur dioxide (SO<sub>x</sub>), nitrogen dioxide (NO<sub>x</sub>), heavy metals and respirable dust particles causing respiratory disorders, heart diseases, lung cancers and many other acute diseases. A similar study

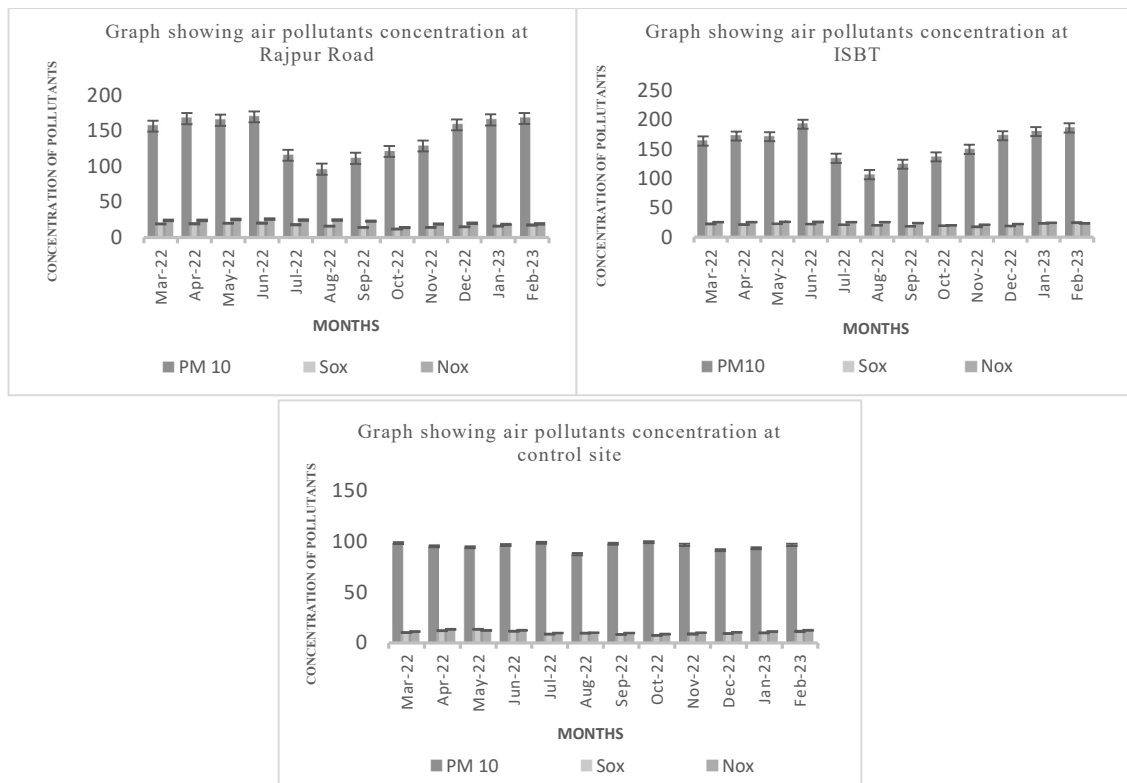


Fig. 4: Graphs of pollutants at three sites.

Table 6: Photosynthetic pigments at three different sites.

	Chl <i>a</i>	Chl <i>b</i>	Total Chl	Carotenoid
Rajpur road	1.94±0.42	1.37±0.19	3.33±0.57	0.82±0.30
ISBT	0.86±0.20	0.61± 0.2	1.48±0.38	0.65± 0.26
Control site	2.12±0.55	1.49±0.3	3.63±0.82	1.05±0.32

\*Mean ± Standard Deviation

took place in Keonjhar district of Odisha, where they selected 8 monitoring sites and monitored air quality for three years and observed that the air quality is worsening every year, though the SO<sub>x</sub> and NO<sub>x</sub> concentrations were still found under the standards set by CPCB (Dash et al. 2023).

### Variation in Photosynthetic Pigments in Litchi Plant at Different Sites

The variation in the chlorophyll concentration was observed at three different sites (Table 6 and Fig. 5). Chlorophyll *a*, *b* and total chlorophyll content were observed to be low at ISBT 0.86 ± 0.20, 0.61 ± 0.2, 1.48 ± 0.38, respectively. Carotenoid content was also observed to be low at ISBT 0.65 ± 0.26. At the same time, the highest concentration was noted at the controlled site, 2.12 ± 0.55, 1.49 ± 0.3, and 3.63 ± 0.82, respectively. At the same time, carotenoid concentration was noted as 0.82 ± 0.30, 0.65 ± 0.26, and 1.05 ± 0.32 at Rajpur Road, ISBT and Control site, respectively.

Chlorophyll *a* is a molecule found in every plant cell, so its concentration is what is measured and reported in a

chlorophyll analysis. Chlorophyll is not an energy-absorbing pigment, but some of the others are. Examples of accessory pigments include carotenoids, xanthophylls, and chlorophyll *b* (Chauhan & Joshi 2008).

A similar study took place in Dehradun on the mango plant, peepal plant and Ashoka tree by Chauhan (2010), where he observed the chlorophyll content, relative water content, and APTI of the plants as per observation. The mango plant was found to be the least tolerant of air pollution. Another study took place on the litchi plant at Muzaffarpur thermal plant, Muzaffarpur (Kumar 2016), where they observed a maximum reduction of about 33% and 50% in chlorophyll *a* and *b* content, respectively. In Haridwar, such of study took place in the year 2006 on the wheat and mustard crop, where they observed the deduction in the chlorophyll *a* and *b* content and ascorbic acid content (Joshi et al. 2009). In Kathmandu, Nepal few species viz., *Ficus benjamina*, *Buddleja asiatica*, *Jacaranda mimosifolia*, *Cinnamomum camphora*, and *Callistemon viminalis* APTI have also been calculated were It was found that *Ficus benjamina*, *Cinnamomum camphora* and *Jacaranda mimosifolia* are intermediate tolerant, and *Buddleja asiatica* was evaluated as a poor performer (Sapkota & Shrestha 2024). Tolerance levels were also tested for plants like *Ficus benghalensis* L., *Polyalthia longifolia*, *M.indica*, *A. indica*, *Delonix regia*, and *Ficus religiosa* L. at New Delhi were two sites, polluted and non-polluted, were selected

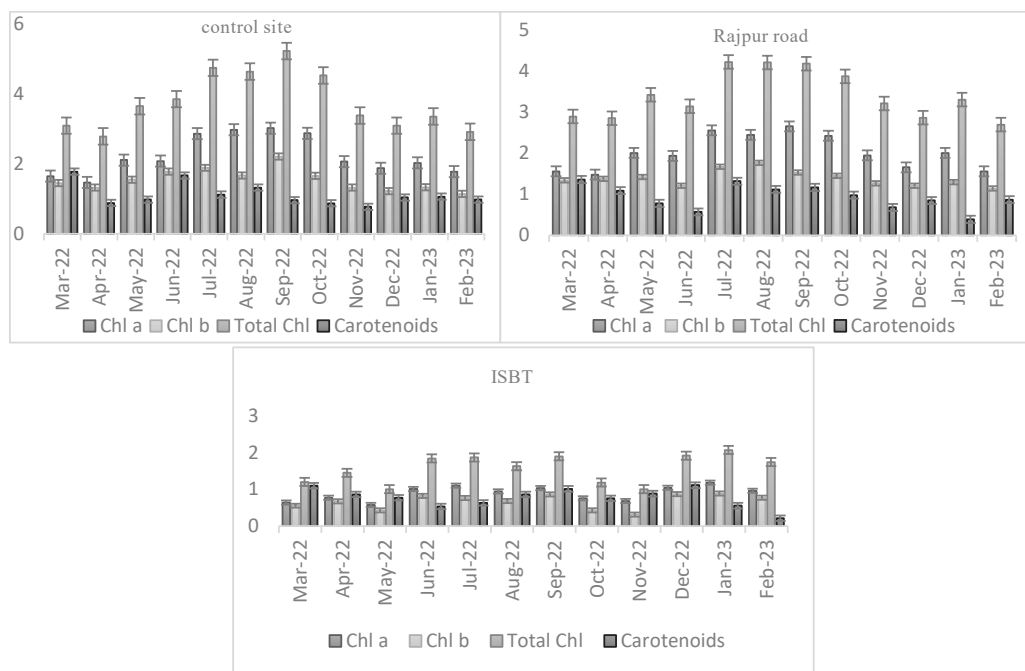


Fig. 5: Graphs of photosynthetic pigments at three sites.

for observation (Tripathi & Nema 2023), and the seasonal variations in the biochemical parameters of the selected plant species were noticed.

### Correlation Between the Air Pollutants with the Total Chlorophyll Content at Three Selected Sites

The correlation graphs (Figs. 6, 7 and 8) show a negative correlation, which means that when the pollutant concentration increases in the surrounding air, the chlorophyll content of the plant may alter. One of the studies concluded that the chlorophyll *a* and *b* altogether tell the correlation and seem informative to tell which plant is tolerant towards air pollution, carotenoids do not play any predictive role because their changes are similar to those in chlorophyll content (Canas et al. 1997). Correlation explains the link between variables. Dutta et al. (2021) studied the urban air quality at Delhi and Kolkata, and using three years' daily mean concentrations from 2017 to 2020, Pearson's correlation coefficients explain AQI-air pollutant relationships in this

investigation. It reveals substantial positive associations between AQI,  $PM_{10}$ ,  $SO_2$ ,  $NO_2$ , and  $PM_{2.5}$  in Kolkata. In order of correlation, AQI and  $PM_{10}$  have the highest correlation (0.99), followed by  $NO_2$  and  $SO_2$  (0.83 and 0.62, respectively). Greater  $PM_{10}$  levels mean greater AQI.

### Biochemical Reaction of Plants Against Air Pollution

Urban air pollution is a problem in both industrialised and developing countries (Jahan & Iqbal, 1992). Toxic gases and other pollutants have been steadily spreading due to the exponential growth of both industrial production and the number of vehicles on the road (Li 2003). As a defence mechanism, plants employ a cascade of metabolic reactions to lessen the impact of air pollution. Enzymes such as peroxidase, catalase, and superoxide dismutase are part of plants' antioxidant systems; they neutralise reactive oxygen species (ROS) generated by pollution. This is an important strategy.

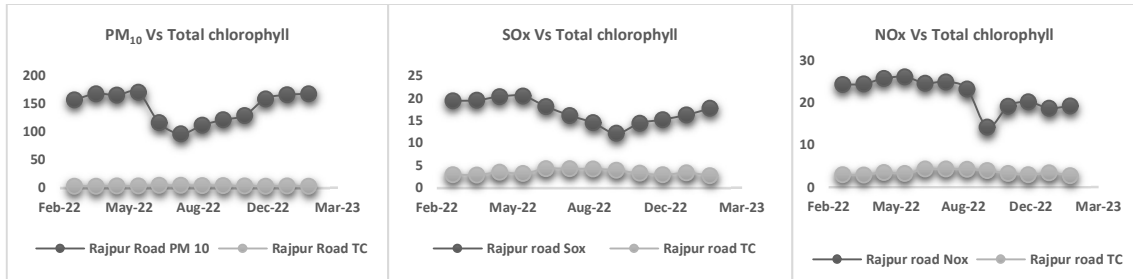


Fig. 6: Graph showing the correlation between  $PM_{10}$ ,  $SO_x$  and  $NO_x$  with total chlorophyll content at Rajpur Road.

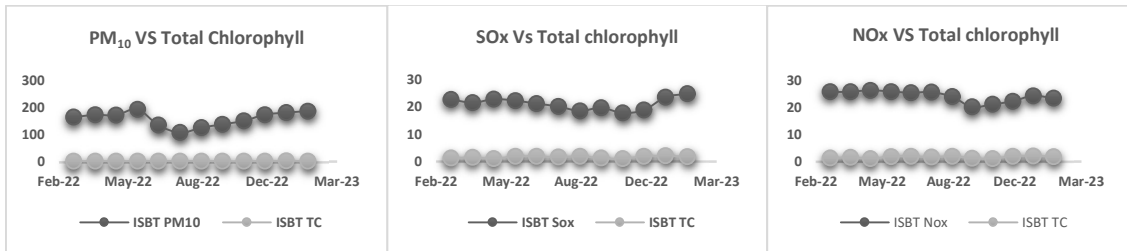


Fig. 7: Graph showing the correlation between  $PM_{10}$ ,  $SO_x$  and  $NO_x$  with total chlorophyll content at ISBT.

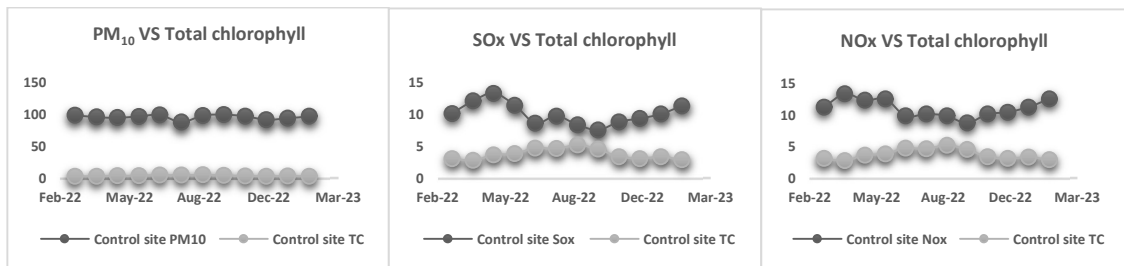


Fig. 8: Graph showing the correlation between  $PM_{10}$ ,  $SO_x$  and  $NO_x$  with total chlorophyll content at the Control Site.

Plants up their production of antioxidant secondary metabolites like flavonoids and phenolics to further combat oxidative stress. Pollutants, by entering plant tissues through stomata, air pollutants can cause an increase in reactive oxygen species (ROS) that can damage DNA, proteins, and lipids (Shannigrahi et al. 2004). To shield themselves from oxidative stress, plant cells have a number of antioxidative defence mechanisms (Kangasjarvi et al. 1994, Dixit et al. 2001, Govindaraju et al. 2012). These defence systems consist of both enzymatic antioxidant enzymes like glutathione reductase and ascorbate peroxidase, and non-enzymatic metabolites like tocopherol and carotenoids and glutathione, and ascorbate. Induction of the detoxification pathway is another important biological event. Plants activate genes that produce enzymes like glutathione S-transferases and cytochrome P450s to help break down and remove pollutants. Through this detoxifying process, plants are better able to tolerate pollutants, including heavy metals and volatile chemical compounds.

Furthermore, stress-response genes are activated in plants by biochemical signalling. Their signalling compounds activate defensive mechanisms, some of which include ethylene and jasmonic acid. The signalling pathways in plants make them more resistant to pollution-induced stress by regulating many physiological processes. To sum up, plants' biochemical reactions to air pollution involve signalling pathways, detoxifying pathways, and antioxidant defence systems. We need to know how plants react so we can find ways to make them more resistant to the increasing levels of environmental pollution.

## CONCLUSIONS

Ultimately, this study fills a significant knowledge gap regarding the effects of air pollution on the photosynthetic pigments of Litchi plants in Dehradun. It provides a thorough investigation of the topic, which has significance for both environmental preservation and human well-being. The results might help lawmakers protect plant health and the ecosystem as a whole by pointing them in the direction of successful mitigation solutions. Poor air quality is a growing problem in developing countries like India due to industrialisation, urbanisation, and rising energy demand. Chlorophyll is the primary light-detecting pigment in photosynthesis. In the chemical process known as photosynthesis, carbohydrates and oxygen are "fixed" from carbon dioxide. There may be a decline in the chlorophyll and pigment content of the leaves of various plants due to the restriction of photosynthetic activity brought on by the various contaminants. Population growth, industrial expansion, urbanisation, and rising vehicle ownership are

all major contributors to rising levels of both primary and secondary air pollution. The rapid growth of the industrial sector is positively correlated with the growing human population and the rising demand from that population, suggesting the possibility of industrial sector expansion. Strict laws should be followed to control air pollution because plants play a crucial role in maintaining air quality. If these plants are not left, then the existence of humans will be in danger.

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