



<https://africanjournalofbiomedicalresearch.com/index.php/AJBR>

Afr. J. Biomed. Res. Vol. 27(4s) (December 2024); 13021-13027

Research Article

Effects Of Vehicular Pollution On Chlorophylls In Leaf Of The Selected Plants.

Nidhi Chaturvedi and Megha Sharma*

*Department of botany, Apex university, Jaipur_302002, Rajasthan, India. Megha98sharma@gmail.com

*Corresponding Author: Megha Sharma

ABSTRACT

The current study illustrates detrimental effects of vehicular air pollutants on overall plant health and productivity of roadside plants in Jaipur. The malicious effects of vehicular pollution was examined on health of eight different plant species, namely, *Acacia nilotica*, *Prosopis juliflora*, *Tamarindus indica*, *Ziziphus jujuba*, *Cassia fistula*, *Cynodon dactylon*, *Tecomella undulata* and *Argemone mexicana* growing in polluted and non-polluted sites of Jaipur. The harmful effects of pollutants were assessed by measuring four different parameters in plants, including, Chlorophyll a, chlorophyll b, total chlorophyll and leaf pH. The results of the study showed decline in chlorophyll a content of all the plant species growing in polluted sites. Similar results were obtained in case of chlorophyll b and total chlorophyll, where too, decline was observed in both the values for plants growing in polluted sites. Similarly, plants growing in polluted sites showed lower leaf pH in comparison to plants growing in polluted sites, indicative of acidification of plant leaves. The findings of the current study are a reflection of obnoxious effects of air pollutants on overall plant health and productivity and highlight the requirement for implementation of management strategies to ameliorate this situation

Keywords: Air pollution, vehicular traffic, chlorophyll a, chlorophyll b, total chlorophyll, leaf pH

*Author for correspondence: Email: Megha98sharma@gmail.com

Received: 17/09/2024, Accepted: 22/10/2024

DOI: <https://doi.org/10.53555/AJBR.v27i4S.6586>

© 2024 The Author(s).

This article has been published under the terms of Creative Commons Attribution-Noncommercial 4.0 International License (CC BY-NC 4.0), which permits noncommercial unrestricted use, distribution, and reproduction in any medium, provided that the following statement is provided. "This article has been published in the African Journal of Biomedical Research"

INTRODUCTION

Environmental pollution has become a critical challenge in the last few decades, owing to its profound effects on various ecosystems as well as the organisms that inhabit these ecosystems. Among various forms of prevalent environment pollution, vehicular emissions have been particularly deleterious, because of their ability to introduce a range of toxic substances and obnoxious gases into the atmosphere, leading to compromise air quality. This obnoxious air filled with toxic gases is not only detrimental to human health but also poses a significant risk to plant health. Plants occupy the centre stage in this intricately woven food web and serve as essential components of terrestrial ecosystems, owing to

their ability to not only contribute to biodiversity but also execution of a prominent role in maintaining ecological balance, carbon sequestration, as well as providing oxygen for sustenance of life on earth. Therefore, it is very important to understand the impact of air pollution on plant physiology and assessment of ecological health of plants, in order to bring about implementation of effective conservation strategies for ensuring plant safety [1-4].

A very important aspect of plant physiology that occurs owing to environmental stress is reduction in chlorophyll content of plants, which is directly linked with a plant's ability to photosynthesize. Chlorophyll is responsible for capturing light energy and brings about

the conversion of sunlight into chemical energy of food for plants. Exposure of plants to pollutants leads to various physiological changes in plants, including reductions in chlorophyll a and b concentrations, decreased photosynthetic efficiency, impaired plant growth, and ultimately, plant mortality if the exposure persists for longer duration. In addition to chlorophyll content in plants, leaf pH also serves as an important indicator of plant health and lower pH values have been linked with increased acidity and potential toxicity in plants [5-6].

Considering this, the current study has been drafted to investigate the effects of vehicular pollution on chlorophyll content as well as leaf pH in several plant species, including *Acacia nilotica*, *Prosopis juliflora*, *Tamarindus indica*, *Ziziphus jujuba*, *Cassia fistula*, *Cynodon dactylon*, *Tecomella undulata*, and *Argemone mexicana*. The study attempts to compare various parameters in plants growing in polluted and non-polluted areas, such as assessing the extent of decline in chlorophyll a and b, total chlorophyll content, as well as leaf pH values. The findings of the study will not only highlight the physiological repercussions of air pollution on different plant species but also provide crucial insights into the broader implications of air pollution on ecosystem health.

MATERIALS AND METHODS

Collection of plants

Plants were collected from different locations of Jaipur district, Rajasthan. All the study sites were divided into 2 classes- pollutant (Bassi, Tunga, Chaksu and Kothwada) and non-pollutant (Amber, Jhotwara, Sanganer and Jobner) on the basis of vehicular activities. Total 8 plants were included in the study which are *Acacia nilotica*, *Prosopis juliflora*, *Tamarindus indica*, *Ziziphus jujuba*, *Cassia fistula*, *Cynodon dactylon*, *Tecomella undulata* and *Argemone mexicana*.

Determination of photosynthetic pigments

Total chlorophyll of the selected plants were calculated by the Arnon method (1949). Fresh leaves of mature plants of the selected species were taken, separately. One-gram fresh leaves was weighed from control and each treatment, separately. The leaves were quickly grinded and homogenized with 40ml of 80% acetone with the help of mortar and pestle. Sample processing was carried out in dark condition to avoid photobleaching and to prevent any pheophytin formation a pinch of NaHCO_3 was mixed with that. The homogenate was processed in centrifuge and upper parts were taken in separate tubes. This step was repeated thrice for the complete extraction of pigments. After that the volume of each supernatant was raised to 100 ml

with 80% acetone. Obtained clear supernatant was studied for the total chlorophyll.

Chlorophyll Quantification

The OD at 645nm, 652nm and 663nm of each sample was taken by spectrophotometer against the blank (80% acetone) for the calculation of the total amount of chlorophyll. Three replicates were taken and the quantity of Chlorophyll a, b was calculated in mg/g of sample by using the equation derived by Arnon, (1949) as follows:

$$\text{Chlorophyll a} = \frac{11.3A_{663} - 0.96A_{645}}{\alpha \times 1000 \times w} \times V$$

$$\text{Chlorophyll b} = \frac{18.3A_{645} - 3.9A_{663}}{\alpha \times 1000 \times w}$$

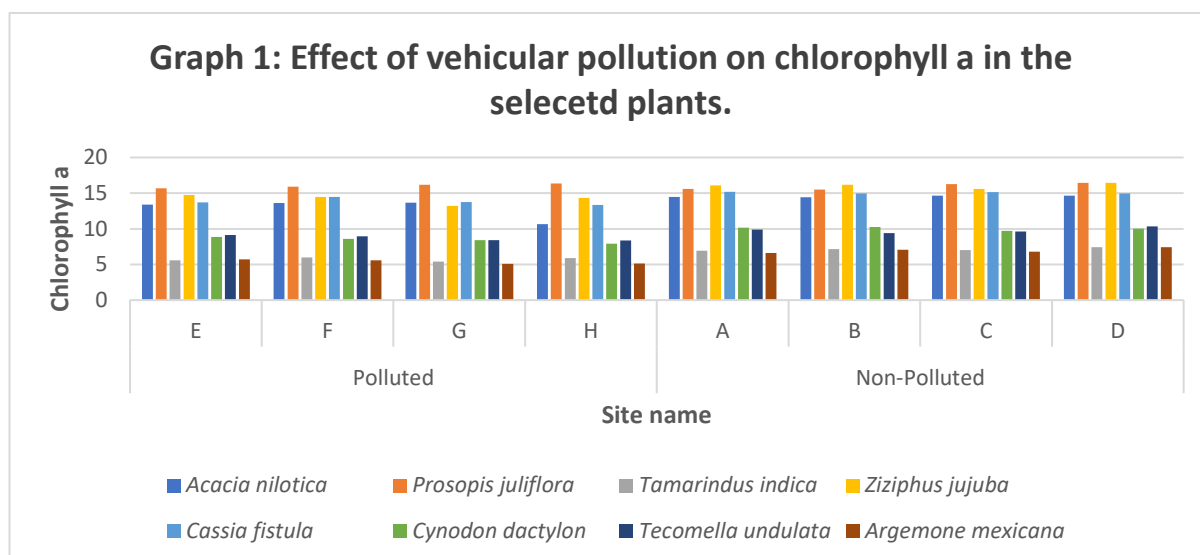
(Where, A = Absorbance; α = Length of the light path in the cell (1 cm); V = Volume of each sample (ml); w = weight of the sample used in gm.)

Besides these, pH of leaf extracts was measured using pH meter.

RESULTS

Effect of air pollution on chlorophyll a content of different plants

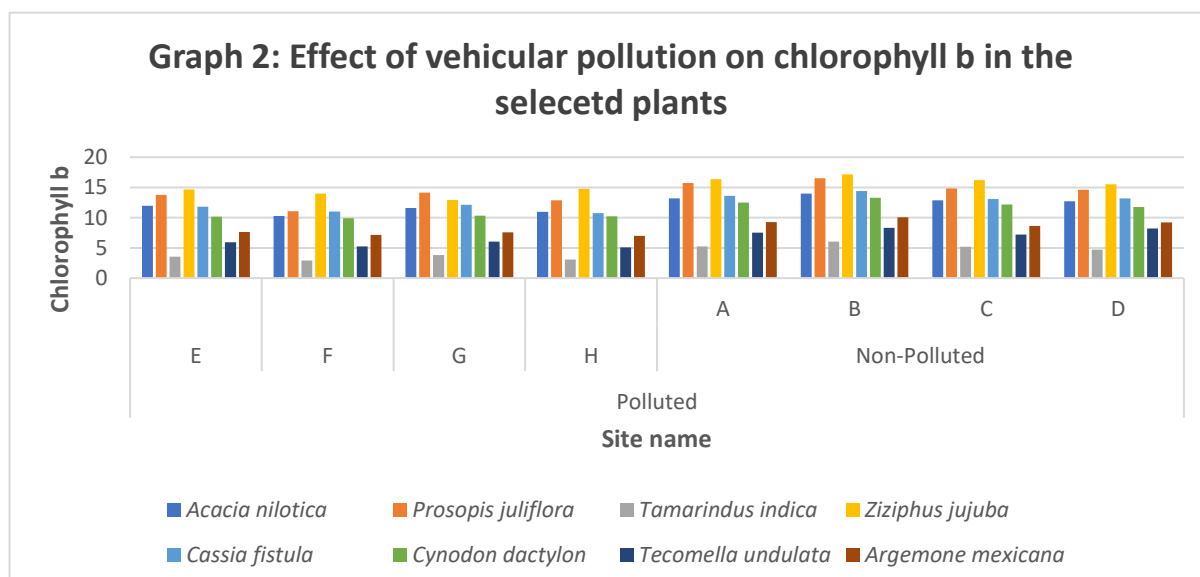
The results in Graph 1 show chlorophyll a content of 8 different plants (*Acacia nilotica*, *Prosopis juliflora*, *Tamarindus indica*, *Ziziphus jujuba*, *Cassia fistula*, *Cynodon dactylon*, *Tecomella undulata* and *Argemone mexicana*) in different sites of Jaipur city, including four non-polluted sites, which experience low vehicular traffic (Bassi, Tunga, Chaksu and Kothwada) and four polluted sites, which experience high vehicular traffic (Amber, Jhotwara, Sanganer and Jobner). The results show high chlorophyll a content in plants growing in non-polluted sites, with chlorophyll a content ranging from *Acacia nilotica* (14.42-14.65 mg/g d.wt.), *Prosopis juliflora* (15.48-16.44 mg/g d.wt.), *Tamarindus indica* (6.92-7.44 mg/g d.wt.), *Ziziphus jujuba* (16.08-16.43 mg/g d.wt.), *Cassia fistula* (14.94-15.20 mg/g d.wt.), *Cynodon dactylon* (9.7-10.25 mg/g d.wt.), *Tecomella undulata* (9.39-10.32 mg/g d.wt.) and *Argemone mexicana* (6.81-7.44 mg/g d.wt.). In contrast to this, chlorophyll a content was comparatively lower in plants growing in polluted sites, with chlorophyll a content ranging from *Acacia nilotica* (10.65-13.64 mg/g d.wt.), *Prosopis juliflora* (15.69-16.35 mg/g d.wt.), *Tamarindus indica* (5.4-6 mg/g d.wt.), *Ziziphus jujuba* (13.19-14.73 mg/g d.wt.), *Cassia fistula* (13.35-14.48 mg/g d.wt.), *Cynodon dactylon* (7.9-8.84 mg/g d.wt.), *Tecomella undulata* (8.39-9.12 mg/g d.wt.) and *Argemone mexicana* (5.08-5.7 mg/g d.wt.).



Effect of air pollution on chlorophyll b content of different plants

The results in Graph 2 show chlorophyll b content of 8 different plants (*Acacia nilotica*, *Prosopis juliflora*, *Tamarindus indica*, *Ziziphus jujuba*, *Cassia fistula*, *Cynodon dactylon*, *Tecomella undulata* and *Argemone mexicana*) in different sites of Jaipur city, including four non-polluted sites, which experience low vehicular traffic (Bassi, Tunga, Chaksu and Kothwada) and four polluted sites, which experience high vehicular traffic (Amber, Jhotwara, Sanganer and Jobner). The results show high chlorophyll b content in plants growing in non-polluted sites, with chlorophyll b content ranging from *Acacia nilotica* (12.7-13.98 mg/g d.wt.), *Prosopis juliflora* (14.62-16.53 mg/g d.wt.), *Tamarindus indica*

(4.7-6.03 mg/g d.wt.), *Ziziphus jujuba* (15.53-17.15 mg/g d.wt.), *Cassia fistula* (13.08-14.41 mg/g d.wt.), *Cynodon dactylon* (11.73-13.3 mg/g d.wt.), *Tecomella undulata* (7.19-8.3 mg/g d.wt.) and *Argemone mexicana* (8.64-10.07 mg/g d.wt.). In contrast to this, chlorophyll b content was comparatively lower in plants growing in polluted sites, with chlorophyll b content ranging from *Acacia nilotica* (10.26-11.97 mg/g d.wt.), *Prosopis juliflora* (11.05-13.74 mg/g d.wt.), *Tamarindus indica* (2.89-3.81 mg/g d.wt.), *Ziziphus jujuba* (12.9-14.77 mg/g d.wt.), *Cassia fistula* (10.75-12.14 mg/g d.wt.), *Cynodon dactylon* (9.9-10.34 mg/g d.wt.), *Tecomella undulata* (5.09-6.03 mg/g d.wt.) and *Argemone mexicana* (6.99-7.60 mg/g d.wt.).



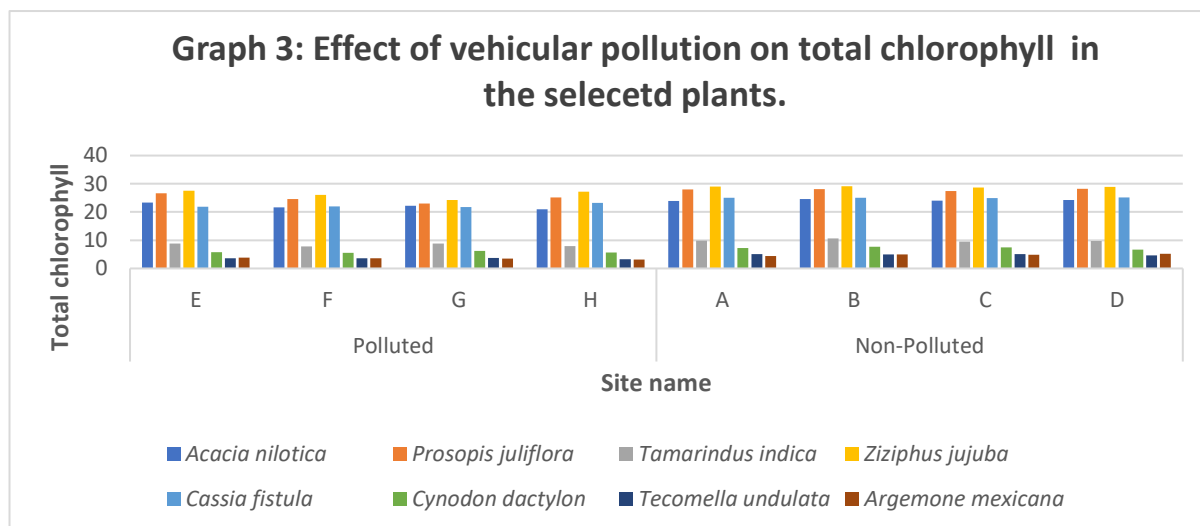
Effect of air pollution on total chlorophyll content of different plants

The results in Graph 3 show total chlorophyll content of 8 different plants (*Acacia nilotica*, *Prosopis juliflora*, *Tamarindus indica*, *Ziziphus jujuba*, *Cassia fistula*, *Cynodon dactylon*, *Tecomella undulata* and *Argemone mexicana*) in different sites of Jaipur city, including

four non-polluted sites, which experience low vehicular traffic (Bassi, Tunga, Chaksu and Kothwada) and four polluted sites, which experience high vehicular traffic (Amber, Jhotwara, Sanganer and Jobner). The results show high total chlorophyll content in plants growing in non-polluted sites, with chlorophyll a content ranging from *Acacia nilotica* (23.91-24.59 mg/g d.wt.), *Prosopis*

juliflora (27.42-28.21 mg/g d.wt.), *Tamarindus indica* (9.76-10.59 mg/g d.wt.), *Ziziphus jujuba* (28.63-29.15 mg/g d.wt.), *Cassia fistula* (24.98-25.21 mg/g d.wt.), *Cynodon dactylon* (6.67-7.71 mg/g d.wt.), *Tecomella undulata* (4.63-5.11 mg/g d.wt.) and *Argemone mexicana* (4.42-5.21 mg/g d.wt.). In contrast to this, total chlorophyll content was comparatively lower in plants growing in polluted sites, with total chlorophyll content

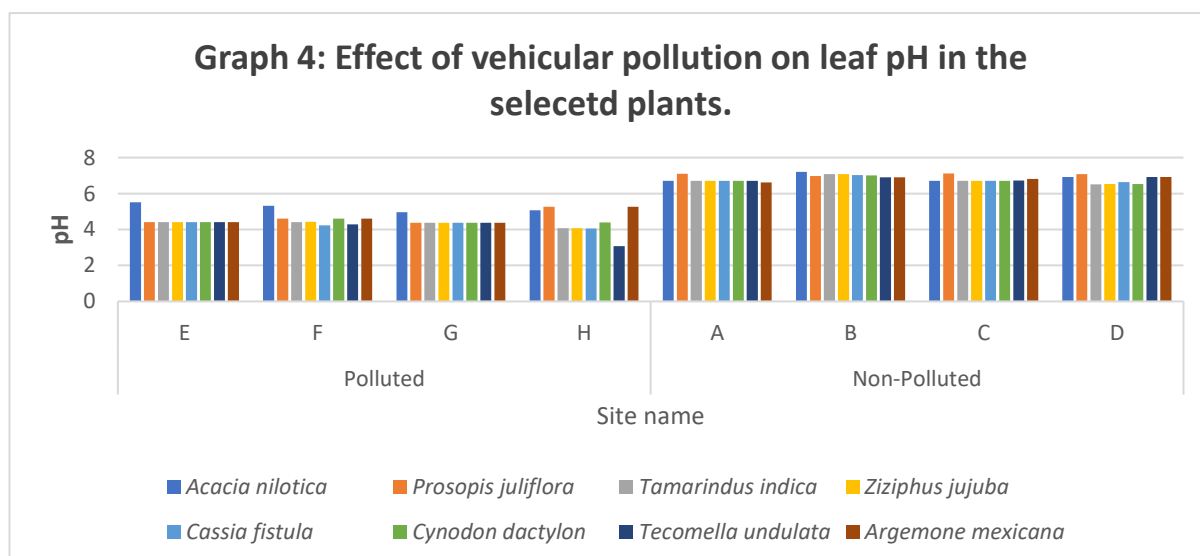
ranging from *Acacia nilotica* (21-23.31 mg/g d.wt.), *Prosopis juliflora* (23-26.61 mg/g d.wt.), *Tamarindus indica* (7.95-8.83 mg/g d.wt.), *Ziziphus jujuba* (24.2-27.5 mg/g d.wt.), *Cassia fistula* (21.75-23.19 mg/g d.wt.), *Cynodon dactylon* (5.52-6.19 mg/g d.wt.), *Tecomella undulata* (3.29-3.75 mg/g d.wt.) and *Argemone mexicana* (3.19-3.85 mg/g d.wt.).



Effect of air pollution on leaf pH of different plants

The results in Graph 4 and its corresponding table show leaf pH content of 8 different plants (*Acacia nilotica*, *Prosopis juliflora*, *Tamarindus indica*, *Ziziphus jujuba*, *Cassia fistula*, *Cynodon dactylon*, *Tecomella undulata* and *Argemone Mexicana*) in different sites of Jaipur city, including four non-polluted sites, which experience low vehicular traffic (Bassi, Tunga, Chaksu and Kothwada) and four polluted sites, which experience high vehicular traffic (Amber, Jhotwara, Sanganer and Jobner). The results show high leaf pH in plants growing in non-polluted sites, with chlorophyll a content ranging from *Acacia nilotica* (6.7-7.2 mg/g d.wt.), *Prosopis juliflora* (6.97-7.11 mg/g d.wt.), *Tamarindus indica* (6.51-7.08

mg/g d.wt.), *Ziziphus jujuba* (6.53-7.08 mg/g d.wt.), *Cassia fistula* (6.64-7.03 mg/g d.wt.), *Cynodon dactylon* (6.53-7.01 mg/g d.wt.), *Tecomella undulata* (6.7-6.92 mg/g d.wt.) and *Argemone mexicana* (6.62-6.92 mg/g d.wt.). In contrast to this, leaf pH was comparatively lower in plants growing in polluted sites, with leaf pH ranging from *Acacia nilotica* (4.97-5.51 mg/g d.wt.), *Prosopis juliflora* (4.37-5.27 mg/g d.wt.), *Tamarindus indica* (4.07-4.41 mg/g d.wt.), *Ziziphus jujuba* (4.07-4.41 mg/g d.wt.), *Cassia fistula* (4.06-4.41 mg/g d.wt.), *Cynodon dactylon* (4.37-4.61 mg/g d.wt.), *Tecomella undulata* (3.07-4.41 mg/g d.wt.) and *Argemone mexicana* (4.37-5.27 mg/g d.wt.).



DISCUSSION

The current study highlights the disastrous impact of vehicular air pollution on eight different roadside plants (including *Acacia nilotica*, *Prosopis juliflora*, *Tamarindus indica*, *Ziziphus jujuba*, *Cassia fistula*, *Cynodon dactylon*, *Tecomella undulata* and *Argemone Mexicana*) in Jaipur growing in areas with heavy vehicular traffic. The findings of the study reveal a concerning relationship between high vehicular traffic and plant health, as evident from significant reductions in various parameters, which include, but are not limited to:

- Amount of chlorophyll a in plants
- Amount of chlorophyll b in plants
- Total chlorophyll concentrations in plants
- Leaf pH of the plants

The results of the study show decline in chlorophyll a content of plants, as evident from average chlorophyll a values of plants declining from *Acacia nilotica* (14.54 mg/g d.wt.), *Prosopis juliflora* (15.94 mg/g d.wt.), *Tamarindus indica* (7.13 mg/g d.wt.), *Ziziphus jujuba* (16.06 mg/g d.wt.), *Cassia fistula* (15.05 mg/g d.wt.), *Cynodon dactylon* (10.03 mg/g d.wt.), *Tecomella undulata* (9.8 mg/g d.wt.), and *Argemone mexicana* (6.97 mg/g d.wt.) in non-polluted areas to lesser values, *Acacia nilotica* (12.82 mg/g d.wt.), *Prosopis juliflora* (16.03 mg/g d.wt.), *Tamarindus indica* (5.72 mg/g d.wt.), *Ziziphus jujuba* (14.18 mg/g d.wt.), *Cassia fistula* (13.82 mg/g d.wt.), *Cynodon dactylon* (8.43 mg/g d.wt.), *Tecomella undulata* (8.69 mg/g d.wt.), and *Argemone mexicana* (5.37 mg/g d.wt.) in polluted areas. The percentage decline in chlorophyll b content of plants was reported to be *Acacia nilotica* (11.85%), *Prosopis juliflora* (-0.56%, indicating an increase), *Tamarindus indica* (19.86%), *Ziziphus jujuba* (11.69%), *Cassia fistula* (8.14%), *Cynodon dactylon* (15.96%), *Tecomella undulata* (11.30%), and *Argemone mexicana* (22.94%). Similar results were obtained in case of chlorophyll b, where too, the results show decline in chlorophyll b content of plants, as evident from average chlorophyll b values of plants declining from, *Acacia nilotica* (13.185 mg/g d.wt.), *Prosopis juliflora* (15.42 mg/g d.wt.), *Tamarindus indica* (5.23 mg/g d.wt.), *Ziziphus jujuba* (16.30 mg/g d.wt.), *Cassia fistula* (13.56 mg/g d.wt.), *Cynodon dactylon* (12.42 mg/g d.wt.), *Tecomella undulata* (7.80 mg/g d.wt.), and *Argemone mexicana* (9.29 mg/g d.wt.) in non-polluted areas to lesser values, *Acacia nilotica* (11.19 mg/g d.wt.), *Prosopis juliflora* (12.94 mg/g d.wt.), *Tamarindus indica* (3.33 mg/g d.wt.), *Ziziphus jujuba* (14.08 mg/g d.wt.), *Cassia fistula* (11.42 mg/g d.wt.), *Cynodon dactylon* (10.16 mg/g d.wt.), *Tecomella undulata* (5.57 mg/g d.wt.), and *Argemone mexicana* (7.33 mg/g d.wt.) in polluted areas. The percentage decline in chlorophyll b content of plants was reported to be *Acacia nilotica* (15.12%), *Prosopis juliflora* (16.17%), *Tamarindus indica* (36.31%), *Ziziphus jujuba* (13.57%), *Cassia fistula* (15.82%), *Cynodon dactylon* (17.99%), *Tecomella undulata* (28.57%), and *Argemone mexicana* (21.04%).

The study shows similar findings in case of total chlorophyll content of plants, wherein, the results show decline in total chlorophyll content of plants, as evident

from average chlorophyll values of plants declining from, *Acacia nilotica* (24.18 mg/g d.wt.), *Prosopis juliflora* (27.94 mg/g d.wt.), *Tamarindus indica* (9.93 mg/g d.wt.), *Ziziphus jujuba* (28.90 mg/g d.wt.), *Cassia fistula* (25.07 mg/g d.wt.), *Cynodon dactylon* (7.25 mg/g d.wt.), *Tecomella undulata* (4.96 mg/g d.wt.), and *Argemone mexicana* (4.87 mg/g d.wt.) in non-polluted areas to lesser values, *Acacia nilotica* (22.03 mg/g d.wt.), *Prosopis juliflora* (24.85 mg/g d.wt.), *Tamarindus indica* (8.36 mg/g d.wt.), *Ziziphus jujuba* (26.23 mg/g d.wt.), *Cassia fistula* (22.18 mg/g d.wt.), *Cynodon dactylon* (5.77 mg/g d.wt.), *Tecomella undulata* (3.55 mg/g d.wt.), and *Argemone mexicana* (3.54 mg/g d.wt.) in polluted areas. The percentage decline in chlorophyll b content of plants was reported to be *Acacia nilotica* (8.92%), *Prosopis juliflora* (11.24%), *Tamarindus indica* (15.73%), *Ziziphus jujuba* (9.24%), *Cassia fistula* (11.53%), *Cynodon dactylon* (20.41%), *Tecomella undulata* (28.52%), and *Argemone mexicana* (27.43%).

The noteworthy declines in chlorophyll a, chlorophyll b and total chlorophyll content are indicative of impaired photosynthetic efficiency of plants in response to malicious effects of vehicular exhaust gases. Chlorophyll a is the primary plant pigment involved in execution of photosynthesis and plays a crucial role in capturing light energy for photosynthesis. On the other hand, chlorophyll b facilitates the process of capturing light energy by broadening the spectrum of light absorption by chlorophyll a molecule [7-8]. The reduction of both chlorophyll a and chlorophyll b indicates impairment in ability of plants to harness solar energy needed for growth and biomass of plants in polluted urban environments. The findings of this study are in perfect agreement with previous studies wherein researchers have demonstrated obnoxious effects of air pollutants—specifically nitrogen oxides, sulfur dioxides, as well as particulate matter in plants [9-10]. Air pollution induced decline in chlorophyll may occur owing to several reasons, the most prominent of them being, impairment of chlorophyll biosynthesis in plants, increased chlorophyll degradation as well as disruption of structure of chloroplast. Sulfur dioxide has been reported to inhibit activity of the enzyme the enzyme δ -aminolevulinic acid dehydratase and consequently cause reduction in chlorophyll biosynthesis [11]. Additionally, nitrogen dioxide triggers oxidative burst in plants and causes lipid peroxidation, increasing degradation of chlorophyll molecule. Deposition of particulate matter affects light penetration efficiency in plants and consequently impairing gaseous exchange and photosynthetic efficiency. Damage to chloroplast structure by air pollutants also affects photosynthesis adversely [13-14]. Additionally, nitrogen metabolism of plants is also affected, leading to retardation of chlorophyll biosynthesis.

A number of other studies have also variability in photosynthetic pigments of plants growing in non-polluted and polluted areas [15-20].

Decline in leaf pH values was also observed in plants of polluted areas, as evident from average leaf pH of non-polluted areas, being, *Acacia nilotica* (6.88.), *Prosopis*

juliflora (7.06 mg/g d.wt.), *Tamarindus indica* (6.75 mg/g d.wt.), *Ziziphus jujuba* (6.75 mg/g d.wt.), *Cassia fistula* (6.77 mg/g d.wt.), *Cynodon dactylon* (6.73 mg/g d.wt.), *Tecomella undulata* (6.81 mg/g d.wt.), and *Argemone mexicana* (6.82 mg/g d.wt.) in non-polluted areas to lesser values, *Acacia nilotica* (5.21 mg/g d.wt.), *Prosopis juliflora* (4.66 mg/g d.wt.), *Tamarindus indica* (4.31 mg/g d.wt.), *Ziziphus jujuba* (4.32 mg/g d.wt.), *Cassia fistula* (4.27 mg/g d.wt.), *Cynodon dactylon* (4.44 mg/g d.wt.), *Tecomella undulata* (4.03 mg/g d.wt.), and *Argemone mexicana* (4.66 mg/g d.wt.) in polluted areas. The percentage decline in pH values of plants was reported to be *Acacia nilotica* (24.29%), *Prosopis juliflora* (33.96%), *Tamarindus indica* (36.22%), *Ziziphus jujuba* (35.88%), *Cassia fistula* (37.01%), *Cynodon dactylon* (34.06%), *Tecomella undulata* (40.89%), and *Argemone mexicana* (31.69%).

The reduction in leaf pH owing to exposure to air pollutants is a particularly intriguing finding. Leaf pH determines optimum execution of many physiological processes, including nutrient uptake as well as crucial enzymatic activities. Reduction in leaf pH is indicative of accumulation of acidic compounds in leaves, which likely occurs owing to deposition of vehicle emissions as well as other environmental pollutants. Reduction in leaf pH can have significant implications for nutrient availability, leading to reduction in availability of certain nutrients under acidic conditions, potentially leading to deficiencies of certain in plants. Similar other studies have been performed and showed decreased leaf pH in response to air pollutants in plants [21-25].

The interaction between decreased leaf pH as well as reduced chlorophyll concentrations is particularly concerning and suggestive of the fact that under acidic condition, impairment of chlorophyll synthesis occurs, further exacerbating the decline in photosynthetic capacity of plants. This creates a vicious cycle of events where impaired photosynthesis leads to reduction in plant growth and health, which in turn may occur owing to even lower leaf pH due to metabolic byproducts. It is very important to understand this relationship for developing effective management strategies in order to mitigate the impacts of urban pollution on plant health.

REFERENCES

1. Seyyednejad SM, Niknejad M, Koochak H. A review of some different effects of air pollution on plants. *Research Journal of Environmental Sciences*. 2011 Apr 1;5(4):302.
2. Han Y, Lee J, Haiping G, Kim KH, Wanxi P, Bhardwaj N, Oh JM, Brown RJ. Plant-based remediation of air pollution: a review. *Journal of Environmental Management*. 2022 Jan 1;301:113860.
3. Diener A, Mudu P. How can vegetation protect us from air pollution? A critical review on green spaces' mitigation abilities for air-borne particles from a public health perspective-with implications for urban planning. *Science of the Total Environment*. 2021 Nov 20;796:148605.
4. Thimmegowda GG, Mullen S, Sottolare K, Sharma A, Mohanta R, Brockmann A, Dhandapany PS, Olsson SB. A field-based quantitative analysis of sublethal effects of air pollution on pollinators. *Proceedings of the National Academy of Sciences*. 2020 Aug 25;117(34):20653-61.
5. Roy A, Bhattacharya T, Kumari M. Air pollution tolerance, metal accumulation and dust capturing capacity of common tropical trees in commercial and industrial sites. *Science of the Total Environment*. 2020 Jun 20;722:137622.
6. Tang L, Xue X, Qu J, Mi Z, Bo X, Chang X, Wang S, Li S, Cui W, Dong G. Air pollution emissions from Chinese power plants based on the continuous emission monitoring systems network. *Scientific Data*. 2020 Oct 5;7(1):1-0.
7. Kato K, Shinoda T, Nagao R, Akimoto S, Suzuki T, Dohmae N, Chen M, Allakhverdiev SI, Shen JR, Akita F, Miyazaki N. Structural basis for the adaptation and function of chlorophyll f in photosystem I. *Nature communications*. 2020 Jan 13;11(1):238.
8. Mandal R, Dutta G. From photosynthesis to biosensing: Chlorophyll proves to be a versatile molecule. *Sensors International*. 2020 Jan 1;1:100058.
9. Khan R, Noorpoor A, Ebadi AG. Effects of air contamination on agriculture. In *Sustainable plant nutrition under contaminated environments 2022* Mar 11 (pp. 1-16). Cham: Springer International Publishing.
10. Abaje IB, Bello Y, Ahmad SA. A review of air quality and concentrations of air pollutants in Nigeria. *Journal of Applied Sciences and Environmental Management*. 2020 Apr 20;24(2):373-9.
11. Siddiqui MH, Alamri S, Alsubaie QD, Ali HM, Ibrahim AA, Alsadon A. Potential roles of melatonin and sulfur in alleviation of lanthanum toxicity in tomato seedlings. *Ecotoxicology and Environmental Safety*. 2019 Sep 30;180:656-67.
12. Liu F, Guo FQ. Nitric oxide deficiency accelerates chlorophyll breakdown and stability loss of thylakoid membranes during dark-induced leaf senescence in *Arabidopsis*. *PLoS One*. 2013 Feb 13;8(2):e56345.
13. Husen A. Morpho-anatomical, physiological, biochemical and molecular responses of plants to air pollution. *Harsh Environment and Plant Resilience: Molecular and Functional Aspects*. 2021:203-34.
14. Singh AK, Kumar M, Baudhh K, Singh A, Singh P, Madhav S, Shukla SK. Environmental impacts of air pollution and its abatement by plant species: A comprehensive review. *Environmental Science and Pollution Research*. 2023 Jul;30(33):79587-616.
15. Sapkota S, Devkota A. Comparative assessment of biochemical characteristics of plants from polluted and non-polluted regions of urban areas. *Oct. J. Env. Res*. 2021;9:1-2.
16. Gaur I, Patel R, Urdukhe Y. Comparative Assessment Of Stomatal Index, Leaf Area, And Chlorophyll Content Of Some Selected Plants From Polluted And None Polluted Areas Of Jalna City. *IJCSPUB-International Journal of Current Scienc (IJCSPUB)*. 2023 Jul;13(3):733-9.

17. Mulenga C, Clarke C, Meincken M. Physiological and growth responses to pollutant-induced biochemical changes in plants: A review.
18. Talebzadeh F, Valeo C. Evaluating the effects of environmental stress on leaf chlorophyll content as an index for tree health. In IOP Conference Series: Earth and Environmental Science 2022 Apr 1 (Vol. 1006, No. 1, p. 012007). IOP Publishing.
19. Ahmad Z, Khan SM, Page SE, Balzter H, Ullah A, Ali S, Jehangir S, Ejaz U, Afza R, Razzaq A, Mukhamezhanova AS. Environmental sustainability and resilience in a polluted ecosystem via phytoremediation of heavy metals and plant physiological adaptations. *Journal of Cleaner Production*. 2023 Jan 20;385:135733.
20. Pilarska M, Niewiadomska E, Sychta K, Słomka A. Differences in the functioning of photosynthetic electron transport between metallicolous and non-metallicolous populations of the pseudometallophyte *Viola tricolor*. *Journal of plant physiology*. 2020 Jul 1;250:153185.
21. Qin J, Jiang X, Qin J, Zhao H, Dai M, Liu H, Chen X. Effects of lead pollution on photosynthetic characteristics and chlorophyll fluorescence parameters of different populations of *Miscanthus floridulus*. *Processes*. 2023 May 19;11(5):1562.
22. Dhal PB, Tripathi S, Devi RS, Singh R, Bhadouria R. Ecophysiological Responses of Tropical Plants to Rising Air Pollution: A Perspective for Urban Areas. In *Ecophysiology of Tropical Plants 2024* (pp. 73-81). CRC Press.
23. Paull NJ, Krix D, Irga PJ, Torpy FR. Green wall plant tolerance to ambient urban air pollution. *Urban Forestry & Urban Greening*. 2021 Aug 1;63:127201.
24. Nagar D, Verma SR, Solanki HA. PHYSIOLOGICAL RESPONSES OF SOME TREE SPECIES UNDER ROADSIDE POLLUTION IN KALUPUR AREA OF AHMEDABAD, GUJARAT.
25. Choudhury S, Parida B, Patro L. Research Article Study of effect of industrial pollutants on morphological and biochemical parameters of some common fruit yielding plants around Vedanta Aluminium Limited, Jharsuguda. *Research Journal of Pharmacy and Life Sciences: Volume*. 2021 Jan;2(1):36-43.