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Research Paper

Assessment of the impact of dust pollution on chlorophyll, carotenoids, and ascorbic acid in the vegetation leaves of some areas in Baghdad – Al-Rusafa, Iraq

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ABSTRACT

Baghdad, one of Iraq's most crowded cities, faces severe air pollution caused by rapid population growth, dense traffic, and limited green spaces. Monitoring at five sites in Al-Rusafa during 2024–2025 showed that pollutant levels, especially PM_{10}, $PM_{2.5}$, and TSP, exceed national and global limits. The most polluted areas lacked vegetation and had heavy traffic, while greener zones showed lower concentrations. Seasonal variations were evident: winter had the highest pollution, summer the lowest but with greater plant stress. Ascorbic acid and the Air Pollution Tolerance Index (APTI) proved reliable indicators of plant resistance. Overall, the study confirms plants' role as effective bio monitors and stresses the need for pollution control in Baghdad's urban areas.

***Keyword*:** Air pollution, Carotenoids, Vegetation, Total suspended particles, Chlorophyll, Air pollution tolerance index (APTI)

Air pollution is one of the most critical global environmental problems, threatening all forms of life. Among its major components are total suspended particles (TSP) and particulate matter (PM), which include PM_{10}, $PM_{2.5}$, and ultrafine particles—tiny airborne solids from both natural and anthropogenic sources (Fernandino *et al.,* 2020). The World Health Organization classified particulate matter as a Group 1 carcinogen due to its deep penetration into the respiratory system and association with cardiovascular, respiratory, and cancer-related deaths, with $PM_{2.5}$ exposure linked to around six million deaths globally in 2024 (WHO, 2021). Natural sources include dust storms, sea spray, and wildfires, while human activities such as fossil fuel combustion, construction, and industrial operations contribute significantly (Ali *et al.,* 2024). Abdulateef *et al.,* (2025) reported that the main factors causing a decrease in air quality are higher temperatures, scanty rainfall, and increased levels of photochemical activity. To mitigate these impacts, expanding urban vegetation is widely recognized as an effective strategy. Trees and shrubs can reduce particulate matter, absorb toxic gases, and lower air temperatures, especially along busy roadways (Wang *et al.,* 2025; Khalid and Rabee, 2025). Vegetative barriers also help limit soil contamination and noise. As highlighted by Xi *et al.,* (2023), integrating green infrastructure into city planning provides a sustainable solution to urban air pollution. Accordingly, this study aims to identify dust-tolerant plant species suitable for cultivation in Baghdad's Al-Rusafa area to improve air quality and promote greener urban environments.

MATERIALS AND METHODS

Study area and observations

The study area is located on Al-Rusafa side of Baghdad, the capital of Iraq, as shown in Fig. 1 and Table 1. Five locations were selected: Al-Adhamiah, Zayouna, Baladiyat, Turath, and Al-Mushtal. Air quality at each site was measured using portable detectors (Temtop LKC-1000s+) for $PM_{2.5}$, PM_{10}, and TSP, placed 1.5 m above ground and aligned with prevailing winds to minimize dust interference. Sampling occurred for one hour, three times per month during peak morning and afternoon hours, across winter 2024 and spring–summer 2025 (Faour *et al.,* 2023). Meteorological data (temperature, humidity, wind speed) and vehicle counts were also recorded. Leaf samples from local plants of similar age and light exposure were collected, with coded samples from multiple plants at each site (Table 2).

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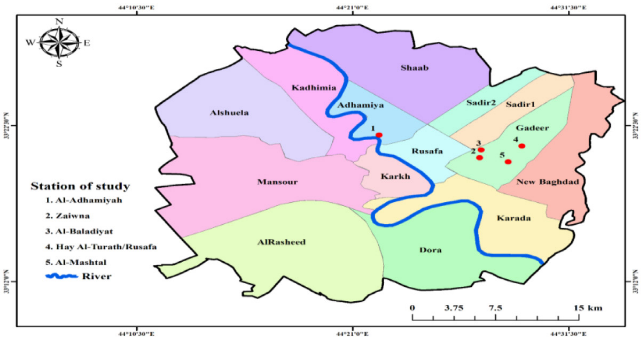

Fig. 1: Shows the study area in Al-Rusafa district of Baghdad

Table 1: Shows the latitude and longitude of the studied areas

Quarter name	Latitude	Longitude
Adhamiyah (A)	33°22′04″N	44°22′12″E
Zaiwna (B)	33°19′35″N	44°27′27″E
Baladiyat (C)	33°20′57″N	44°30′05″E
Turath/ Rusafa (D)	33°13′05″N	44°20′09″E
Mashtal (E)	33°19′30″N	44°29′33″E

Table 2: Plant species and sampling sites across urban areas in Baghdad, Iraq

Site	Plant species/Scientific name
Adhamiyah	*Ficus nitida, Ziziphus spina-christi* (L.) Desf, *Phoenix dactylifera* L., *Senna alexandrina, Albizia labbeck* (L.) Benth., *Hibiscus tiliaceus* (L.)
Zaiwna	*Phoenix dactylifera* L., *Ziziphus spina-christi* (L.) Desf, *Eucalyptus camaldulensis, Cassia fistula* (L.)
Baladiyat	*Ziziphus spina-christi* (L.) Desf, *Phoenix dactylifera* L. *Nerium oleander, Conocarpus lancifolius*
Turath/ Rusafa	*Conocarpus lancifolius, Ziziphus spina-christi* (L.) Desf
Mashtal	*Ziziphus spina-christi* (L.) Desf, *Phoenix dactylifera* L. *Conocarpus lancifolius*

Fully mature leaves of each plant species were randomly collected (25–50 leaves per species, 1.5–2 m height) and transported to the laboratory for analysis. Chlorophyll a, b, total chlorophyll, and carotenoids were extracted from 0.25 g of fresh leaves using 80% acetone in dark conditions, homogenized, centrifuged, and measured with a spectrophotometer at 663.6 nm (chlorophyll a), 646.6 nm (chlorophyll b), and 470 nm (carotenoids). Pigment concentrations were then calculated using established equations (Kotecha and Ram, 2023):

$$\text{Chlorophyll a (mg g}^{-1}\text{)} = [12.25\ A_{663.6} - 2.25\ A_{646.6}] \times V/1000 \times W$$

$$\text{Chlorophyll b (mg g}^{-1}\text{)} = [20.31\ A_{646.6} - 4.91 A_{663.6}] \times V/1000 \times W$$

$$\text{Total Chlorophyll (mg g}^{-1}\text{)} = (20.2\ A_{645} + 8.02\ A_{663}) \times V/1000 \times W$$

$$\text{Total carotenoid (mg g}^{-1}\text{)} = [1000 A_{470} - 2.27(\text{chl.a}) - 81.4(\text{chl.b}) / 227] \times V/1000 \times W$$

The Air Pollution Tolerance Index (APTI) has been established: The tolerance index values for the plant species previously described were determined according to the method proposed by Asif and Ma (2024) and applying the following equation:

Whereas: AA = Ascorbic acid (mg g^{-1} fw); P = pH level; TCH = Total chlorophyll content (mg g^{-1} fw); RWC% = Relative water content; According to the air pollution tolerance values, plants were classified into three categories based on the classification of Sahu *et al.,* (2020): APTI ≥ 17 tolerant, APTI = 12 to 16 moderately tolerant, APTI < 12 sensitive

Statistical analysis

Data were analyzed using IBM SPSS v25.0. Means and standard deviations were reported, with significant differences assessed via ANOVA followed by the LSD test. Pearson's correlation coefficient was used to examine relationships between parameters, with significance set at $p \leq 0.05$ (Smith *et al.,* 2022).

RESULTS AND DISCUSSION

Table 3 shows clear seasonal variations in particulate matter (PM_{10}, $PM_{2.5}$, TSP) and their links to meteorological factors. PM_{10} and TSP varied significantly, peaking at site D in spring and lowest at sites A and E in summer, while $PM_{2.5}$ showed similar but non-significant trends. Relative humidity decreased from winter to summer, temperature ranged from 12 °C to 48 °C, and wind speed was highest in winter (all significant). Vehicle counts showed minimal seasonal change. Overall, particulate levels were mainly influenced by meteorological conditions rather than traffic volume.

Fig. 2 shows that total chlorophyll concentrations varied among plant species and seasons, with the highest values recorded in spring, particularly in *P. dactylifera*, followed by *C. lancifolius*. Concentrations markedly decreased in summer across all species, while winter showed intermediate levels. Overall, total chlorophyll followed the trend: Spring>Winter> Summer.

Fig. 3 indicates clear seasonal and species variations in carotene concentrations. The highest levels were recorded in spring, especially in *P. dactylifera*, followed by *C. lancifolius* and *N. oleander*. Summer showed moderate values, while winter recorded the lowest across all species. Overall, carotene concentrations followed the pattern: Spring > Summer > Winter.

The results (Fig. 4) show that the highest concentration of ascorbic acid was recorded in *Z. spina-christi* during the winter season, followed by *P. dactylifera*, while the lowest concentrations were found in *C. fistula* and *N. oleander*. In general, ascorbic acid concentrations were higher in winter compared to spring and summer across all studied plant species.

The results (Fig. 5) indicate that the highest tolerance index was observed in *Z. spina-christi* during the winter season, followed by *P. dactylifera*, while the lowest values were recorded in *S. alexandrina*, *A. labeck*, and *H. tiliaceus*. Overall, the tolerance index values were higher in winter compared to spring and summer for all studied plant species.

Table 3: Seasonal variations of air pollutants and meteorological parameters (Mean ± SD) at different sites

Site	Winter	Spring	Summer
PM10			
Adhamiyah (A)	134.00 ± 66.04	104.33 ± 42.81	21.33 ± 0.88 *
Zaiwna (B)	143.33 ± 41.43	160.00 ± 73.70	25.33 ± 0.88 *
Baladiyat (C)	185.00 ± 10.69	88.00 ± 35.03	39.67 ± 0.88 *
Turath/ Rusafa (D)	57.33 ± 11.79	196.00 ± 93.56	26.33 ± 0.88 *
Mashtal (E)	105.00 ± 19.86	117.67 ± 59.00	28.67 ± 1.76 *
PM2.5			
Adhamiyah (A)	69.33 ± 38.49	90.33 ± 38.30	34.33 ± 1.20
Zaiwna (B)	46.00 ± 24.42	81.67 ± 35.89	37.00 ± 1.53
Baladiyat (C)	60.33 ± 25.18	107.67 ± 57.07	53.67 ± 4.63
Turath/ Rusafa (D)	88.33 ± 42.40	142.67 ± 70.53	39.33 ± 2.33
Mashtal (E)	97.67 ± 45.48	95.67 ± 46.05	37.00 ± 1.15
TSP			
Adhamiyah (A)	487.33 ± 196.70	665.67 ± 84.05	970.67 ± 48.51 *
Zaiwna (B)	440.33 ± 144.38	1634.33 ± 42.31	767.33 ± 10.74 *
Baladiyat (C)	421.67 ± 101.82	627.00 ± 60.96	984.00 ± 8.62 *
Turath/ Rusafa (D)	796.67 ± 415.20	2525.67 ± 277.72	959.33 ± 31.35 *
Mashtal (E)	796.33 ± 392.83	565.33 ± 48.84	512.00 ± 27.62
RH %			
Adhamiyah (A)	39.00 ± 4.36	31.53 ± 1.57	22.67 ± 0.88 *
Zaiwna (B)	38.00 ± 1.80	33.87 ± 4.08	18.33 ± 0.88 *
Baladiyat (C)	31.37 ± 2.74	26.47 ± 3.50	17.67 ± 1.67 *
Turath/ Rusafa (D)	19.47 ± 0.77	26.00 ± 2.08	18.67 ± 0.88
Mashtal (E)	21.87 ± 6.11	23.67 ± 0.88	17.67 ± 1.76
Temperature (°C)			
Adhamiyah (A)	12.00 ± 1.53	25.20 ± 0.42	41.43 ± 1.80 **
Zaiwna (B)	15.70 ± 1.32	28.07 ± 0.52	47.33 ± 0.88 **
Baladiyat (C)	18.00 ± 1.73	33.97 ± 2.68	47.67 ± 1.45 **
Turath/ Rusafa (D)	21.03 ± 1.49	34.50 ± 2.48	45.67 ± 3.84 **
Mashtal (E)	21.00 ± 1.53	37.33 ± 2.19	45.33 ± 3.71 **
Wind speed (km/h)			
Adhamiyah (A)	25.53 ± 4.90	14.33 ± 3.38	15.33 ± 2.19 *
Zaiwna (B)	11.67 ± 4.67	17.33 ± 0.33	17.00 ± 0.58
Baladiyat (C)	7.63 ± 4.70	16.67 ± 3.18	9.33 ± 0.88 *
Turath/ Rusafa (D)	7.54 ± 2.67	18.00 ± 0.58	10.33 ± 1.20 *
Mashtal (E)	14.50 ± 4.01	16.67 ± 2.40	13.67 ± 1.86
No. of vehicles			
Adhamiyah (A)	8115.7 ± 794.4	7419.0 ± 404.2	8860.3 ± 663.8
Zaiwna (B)	9566.7 ± 435.5	5106.7 ± 282.8	9619.7 ± 934.3
Baladiyat (C)	9966.3 ± 714.9	8691.0 ± 1029.3	7696.7 ± 2886.5
Turath/ Rusafa (D)	11192.0 ± 911.7	9563.3 ± 314.9	7956.0 ± 3246.1
Mashtal (E)	11180.7 ± 1127.5	12158.7 ± 1285.4	40130.3 ± 28990.1 *

Note: * Significant at $p \leq 0.05$ ** Highly significant at $p \leq 0.01$

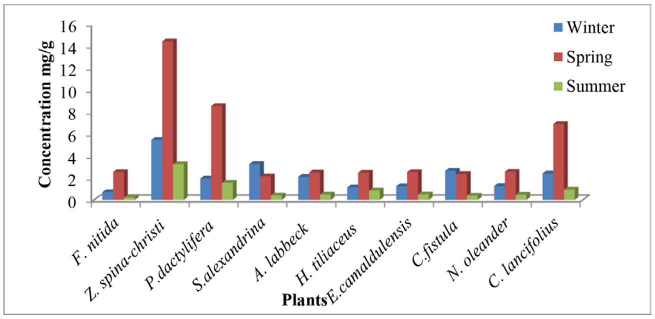

Fig. 2: Mean of total chlorophyll concentrations (mg g^{-1}) at studied plants

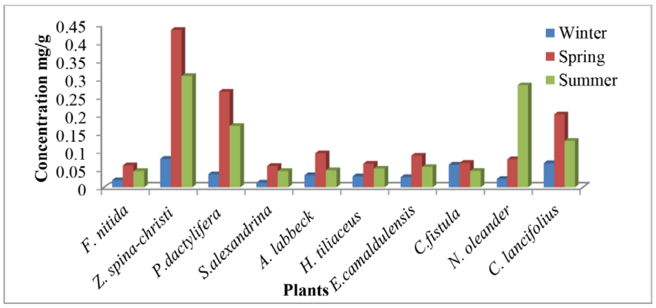

Fig. 3: Mean of carotene concentrations (mg g^{-1}) at studied plants

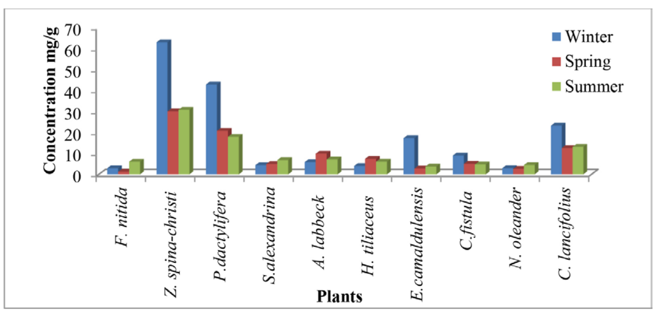

Fig. 4: Mean of ascorbic acid concentrations (mg g^{-1}) at studied plants

Correlation analysis (Table 4) revealed significant relationships between air pollutants, environmental factors, and plant indicators. PM_{10} was positively correlated with relative humidity and negatively with temperature, indicating that cooler, humid conditions favor its accumulation. PM_{10} and $PM_{2.5}$ were moderately correlated, while $PM_{2.5}$ also correlated with TSP, highlighting interconnected particulate behavior. Among biological indicators, chlorophyll positively correlated with the tolerance index, suggesting higher productivity aligns with greater stress tolerance, whereas carotene negatively correlated with ascorbic acid, indicating a possible trade-off in antioxidant allocation under environmental stress.

PM_{10} and $PM_{2.5}$ levels in Iraq are influenced by both natural and human factors, often exceeding WHO limits and posing health risks (WHO, 2021). Concentrations peak in spring due to dust storms and remain high in winter from heating emissions and atmospheric stability, while summer shows the lowest levels because of strong mixing and dispersion (AlObaidi and Al-Salman, 2024; Intan *et al.,* 2024). Overall, dust storms, traffic, and industrial activities are major pollution sources, and although wind aids dispersion, urban structures can trap pollutants. Promoting electric vehicles and stricter regulations can mitigate these effects (Awadh, 2023; Al-Hamd and Jasim, 2025).

Total chlorophyll showed clear seasonal variation, with the highest levels in spring, moderate in winter, and lowest in summer due to temperature and nutrient effects (Wang *et al.,* 2024). Urban sites had higher spring chlorophyll levels, likely from nutrient inputs from human activities (Al-Yasiri and Hadi, 2020). Carotenoid levels in plants are affected by air pollution, as these pigments protect cells from oxidative stress. Their response varies with pollutant type and environmental conditions. Some studies show reduced carotenoids under pollution stress (Rao *et al.,* 2025), while others report increases as a protective mechanism. Seasonal changes reflect both natural and human influences. Overall, carotenoids are reliable bioindicators for assessing air quality and ecological effects (Goswami *et al.,* 2023).

Ascorbic acid levels varied by season and site, reaching their highest in winter and decreasing in spring and summer. These changes are influenced by temperature, light, and nutrient conditions affecting antioxidant activity (Phan *et al.,* 2021). Site differences relate to local factors such as shading and water flow. Overall, vitamin C content depends on both seasonal and environmental conditions (Hasanuzzaman *et al.,* 2013; Al-Hayani and Attarbashi, 2021). Vitamin C concentrations vary by location due to factors such as nutrient availability, organic matter, and pollution. Levels are generally higher in colder seasons and more variable in warmer seasons. As a key antioxidant, ascorbic acid is highly influenced by seasonal and local environmental conditions, making it a useful biomarker for ecological and physiological assessments (Mølmann *et al.,* 2015).

The study found notable variation in the Air Pollution Tolerance Index (APTI) among urban plants. Highly tolerant species suitable for urban greening included *E.camaldulensis*, *Z.spina-christi*, and *C.fistula*, while moderate tolerance was seen in *P.dactylifera*, *C.lancifolius*, and *A.labbeck*. Sensitive species like *F.nitida* and *N.oleander* can serve as bioindicators, with sites such as Zaiwna having more tolerant species (Salih *et al.,* 2017; Jasim *et al.,* 2018).

Air pollutants (PM_{10}) correlate positively with humidity and negatively with temperature, reflecting dispersion dynamics, and show moderate correlations with $PM_{2.5}$ and TSP due to shared urban and dust sources (Mohammed *et al.,* 2020). Chlorophyll levels positively correlate with tolerance, indicating better adaptation at productive sites, while negative correlations between carotene and ascorbic acid reflect metabolic trade-offs under stress (Rodriguez and López, 2023; Wang *et al.,* 2024).

CONCLUSION

This study highlights that air pollution, particularly PM10 and PM2.5, strongly affects plant physiology, with winter being the most impacted season, while semi-rural sites showed greater tolerance compared to traffic-dense urban areas. Species evaluation revealed *Eucalyptus camaldulensis, Ziziphus spina-christi*, and *Cassia fistula* as the most tolerant, whereas *Ficus nitida* and *Senna alexandrina* proved sensitive and suitable as bioindicators. Overall,

Table 4 : Pearson correlation between air quality parameters, meteorological factors, and phytochemical indicators

Parameters	PM10	PM2.5	TSP	RH	Temp	Wind	No. of vehicles	Chlorophyll	Carotenoids	Ascorbic acid	Tolerance index
PM10	1										
PM2.5	.602*	1									
TSP	.316	.514*	1								
RH	.735**	.180	-.078	1							
Temp	-.664**	-.308	.217	-.773**	1						
Wind	.228	.264	.182	.401	-.112	1					
No. of vehicles	-.301	-.258	-.237	-.362	.276	-.084	1				
Chlorophyll	-.268	-.087	-.249	-.154	.201	-.146	-.195	1			
Carotenoids	-.289	-.205	-.111	-.215	.198	-.223	.017	.245	1		
Ascorbic acid	-.169	.072	.330	-.417	.304	-.152	.024	-.217	-.307*	1	
Tolerance index	.026	-.194	-.219	.239	-.336	-.171	-.218	.291*	-.178	.664**	1

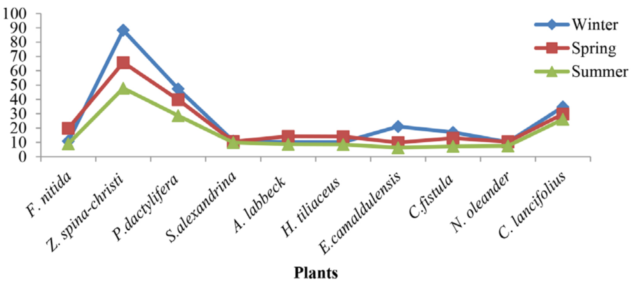

Fig. 5: Mean of tolerance index (mg L^{-1}) at studied sites

plants serve a dual role as natural biofilters and indicators of air quality, emphasizing the importance of integrating tolerant species into urban greening strategies to mitigate pollution impacts.

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Authors contribution:* H. H. Jassim*:* *Conducted the experiments, collected and analyzed the data, and prepared the initial manuscript*. **I. M. A. Al-Salman:* Designed the study, supervised the research process, and contributed to manuscript writing. ***M. A. M. Al-Alwani*:** Conceived the study, provided guidance on methodology, interpreted results, and critically revised the manuscript.

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