Research Article

Air Pollution Tolerance and Biochemical Assessment of Urban Tree Species in Erbil, Iraq: A Comparative Study of (*Morus alba* L. and *Melia azedarach* L.)

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Abstract | This investigation was conducted during summer season from the 1th of September to study the air pollution tolerance index to assess the tolerance of particular tree species. This technique can facilitate the evaluation and screening of sensitive and tolerant alternative tree species in Erbil city. The Air Pollution Tolerance index (APTI) for each species were developed and divided into tolerant, intermediate, and sensitive groups based on a combination of leaf pH, relative water content, total chlorophyll, and ascorbic acid concentrations. Since both studied species under investigation are considered sensitive, their APTIs values were lower in less polluted locations, respectively. In addition, *Morus alba* L. showed the highest values for all recorded parameter except ascorbic acid, which exhibited the lowest value when compared to *Melia azedarach* L. The highest values of ACA and LRWC % were recorded in location 3 for both species (2.63 mg g^{-1}, 88.67 %) respectively. In addition, the highest values of the total chlorophyll and leaf pH were recorded in the location of less polluted site (0.10 mg g^{-1} and 8.69) in *Morus alba* L. It can be conclude that based on APTI recorded values the study findings showed that different species tolerance orders were discovered at the four sampling location as a result of changing in air pollution levels. Overall, the studied tree species were recognized as intolerant of the air pollution environment and not recommended to be planted in all locations across the Erbil city, mainly along heavily traffic roadways.

Received | June 12, 2025; **Accepted** | September 22, 2025; **Published** | June 27, 2026
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Citation | Sabr, H.A., K.A. Ali. 2026. Air Pollution tolerance and biochemical assessment of urban tree species in erbil, iraq: A comparative study of (*Morus alba L.* and *Melia azedarach L.*). *Sarhad Journal of Agriculture,* 42(2): 1061-1071.
DOI | https://dx.doi.org/10.17582/journal.sja/2026/42.2.1061.1071
Keywords | Ascorbic acid, Air pollution, APTI, Relative water content (RWC), Total chlorophyll, Tolerance.

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Introduction

Environmental pollutants have significantly increased in recent decades due to the world's population growth other factors such as increasing number of vehicles and pollution fuel emission from factories. The The increased concentration of pollutants has caused a lot of doubt because of the possible negative effects on plants and human health (Alotaibi *et al*., 2020). The effects of pollutants can be considerably alleviated with the effective application of suitable environmental management approaches (Alotaibi *et al*., 2020). The release of pollutants such as particulate matter from biomass burning has received considerable interest due to its negative effect on human health and the environment (Hassan *et al*., 2020). Air pollution has become known as a life-threatening issue in developing nation's globally attributable fast urbanization and industrialization (Yadav *et al*., 2020). Air pollutants can negatively impact some physiological and biochemical parameters such as pH and relative water content), morphological (leaf area and stomata density), and biochemical like (ascorbic acid and leaf pigments) trait of roadside green spaces (Aleadelat and Ksaibati, 2018).The degree at plant species are susceptible to air pollutants increases in proportion to their persistent properties, an accumulation of dust, the physicochemical traits and the length of time that air pollutants remain in the atmosphere (Janhäll, 2015).

Urban forest trees serve as important natural reservoirs of carbon within terrestrial ecosystems (Ali *et al*., 2023). Trees are recognized for their function in reducing air pollution, thus selection of suitable tree species for a greenbelt project is essential. The morphological and physiological characteristics of tree leaves are considered the most significant factors in assessing susceptibility to varying levels of air pollution (Chavan and Sonwane, 2012). Tree leaves act as an efficient barrier for pollution removal owing to their increased leaf surface area and significantly exposed regions (Rai, 2016). Plants contain ascorbic acid; it protects thylakoid membranes from oxidative damage while also playing a crucial role in regulating cell division and growth under stressful conditions (Akram *et al*., 2017). The tree species present at a specific location can be used to evaluate the pollution levels of that area (Kaur and Nagpal, 2017).

Currently, roadside vegetation is recognized as one of the most effective methods for biomonitoring air pollution and can serve as bio-indicators of atmospheric pollution (Miria and Khan, 2013). A certain degree of air pollution can be reduced by developing green cover through the planting of tolerant species; choosing the right plant species is crucial for any plantation project The Air Pollution Tolerance Index (APTI), which effectively evaluates the influence of pollutants exclusively on biochemical parameters, is a commonly used indicator for plant selection (Supriya *et al*., 2025). These techniques allow to evaluate and measure the degree of bioaccumulation and soil pollution for the selection of plants for ecological restoration (Rasool *et al*., 2025).The anticipated performance index (API) for the green belt air pollution mitigation plan considers specific biological and socioeconomic features. Javanmard *et al*. (2020). According to Sharma *et al*. (2020), the API is a preferable measure compared to the APTI for assessing the capacity of dominant species to remove pollutants from the atmosphere. The study by Shahrukh *et al*. (2023) identified the tolerance or sensitivity of four evergreen trees based on APTI values, determining the most suitable plant species for urban forest development in urban greenbelts. Furthermore, variations in the biochemical parameters of plants were noted. These findings may facilitate the classification of plant species as air pollution sinks and bioindicators (Tripathi and Nema, 2023).

The urban areas of the Erbil are expanding and at the same time facing loss of green vegetation owing to extending out of urban. This may have consequence in dense settlements in the central parts of Erbil city. Developing green spaces is crucial to mitigate the decrease of natural vegetation caused by urbanization, which has resulted in an imbalance in air quality due to the rising number of automobiles. The air pollution tolerance index (APTI) of several tree species in Erbil city has not been evaluated by previous investigations. The enhancement of green spaces tends to mitigate air pollutants and may serve as an inexpensive remedy for air pollution. The primary issue is the restricted awareness necessary for selecting tree species for urban tree cover development. The main purpose of this study is to evaluate the tolerance of specific tree species through the application of the air pollution tolerance index.

Materials and Methods

Study location

Erbil is located in the southern southern part of Kurdistan; it is a capital of Iraqi Kurdistan region. It is situated between the latitudes 35-37 and 45, and the longitudes 43 and 45. It reaches an elevation of 414 meters above sea level. The climatic conditions of Erbil are classified as mild and moderate. Precipitation is more frequent in winter than in summer. The average temperature within this city is 20.3 °C. The annual precipitation is 560 mm and summer begins within the month of June and continues in September.

Species description

Morus alba L.

A *M. alba* belongs to Moraceae family and it is a fast-growing, deciduous, tree that is characterized by a deep root system. *M. alba* is a small to medium-sized tree, reaching heights of up to 15 meters, described by a short trunk and a rounded crown with a dense canopy of spreading branches in an open areas (Janick and Paull, 2008). An investigation into various pharmacological substances of medicinal importance found in *M. alba* tree show new study opportunities in medical science. The study in brief summarize the economic and environmental significance of mulberry, including its various roles as animal feed, food source and in the cleanup of contaminated soils and air (Rahman and Islam, 2021).

Melia azedarach L.

M. azedarach is naturally occurred in Australia and Southeast Asia, and belongs to the Meliaceae family, (Batcher, 2008). It is a deciduous trees species distinguished by a rounded canopy. The tree may grow to an average height of 12 meters at maturity tree diameter may reach nearly 30-60 cm in diameter, (Batcher, 2008). Tree species are frequently cultivated as a shade tree due to its substantial canopy, and also are cultivated in parks, public gardens, riverbanks, and alongside pathways or roadways (Batcher, 2008).

Sample collection

Two tree species *M. alba* L. and *M. azedarach* L. were chosen from among all those planted in Erbil City because of their abundance and ecological value at the chosen location. Samples of leaves were collected from the same tree throughout the summer starting from the 1th of September of both deciduous tree species. All of the trees were already been growing in the chosen areas for many of years and were pest-free, healthy, and in good condition as documented by Bala *et al.* (2022).In addition, to minimize variations caused by precipitation; the leaf sample collection was also done earlier to any rainfall. Four study sites in Erbil were selected altogether (L1: Sami Abdulrhaman Park, as a location with less pollution, L2: 100 m ring road, L3: 60 m ring road, and L4: 30 m ring road), as indicated by the feature descriptions of each sampling location in Table 1.

The selected trees that were available at the experiment site were chosen for the investigation. Immediately as samples were arrived at the lab, the fresh weight of the leaves was measured. Leaf samples for additional analysis were kept in a refrigerator (Dzierżanowski *et al.*, 2011). To enable the quantification of the other parameters, each part of the samples from each species was carefully stored in plastic bags and kept at room temperature as mentioned by Zhange *et al.* (2020). For every species, we obtained at least 150 healthy leaves from three randomly chosen trees (replicates) that were between one and two meters above the ground, depending on the structure and habitat of the trees, and growing on the side that was exposed to traffic (Dzierżanowski *et al.*, 2011).

Table 1: *Location of leave sampling.*

Locations	sp. Name	N	E	Elevation(masl)
L1	S1	36.19787	43.98349	387
	S2	36.19651	44.0161	387
L2	S1	36.16207	44.03247	434
	S2	36.18269	43.96154	429
L3	S1	36.20234	44.00476	413
	S2	36.20289	44.01501	421
L4	S1	36.19827	44.10595	412
	S2	36.19645	44.1537	427

Note: S1: Morus alba L. S2: Melia azedarcha L.

Air pollution tolerance index

Fresh leaf samples were collected to assess biochemical parameters, including total chlorophyll, ascorbic acid, and relative moisture content, as well as to measure the pH of the leaf extract, from which the Air Pollution Tolerance Index (APTI) was calculated. The below equation was used to calculate APTI as documented by (Al-Healy and Ibrahim. 2022) and Singh and Rao (1983).

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

Where,

A is ascorbic acid content (mg g^{-1}), *P* the pH of leaf extract, *T* the total chlorophyll content (mg g^{-1}), and *R* the relative water content (%) of fresh leaves

Ascorbic acid (ACA) mg g^{-1}

The concentration of ascorbic acid (ACA) in leaves was measured according to the method was used by

Watson and Bai (2021).

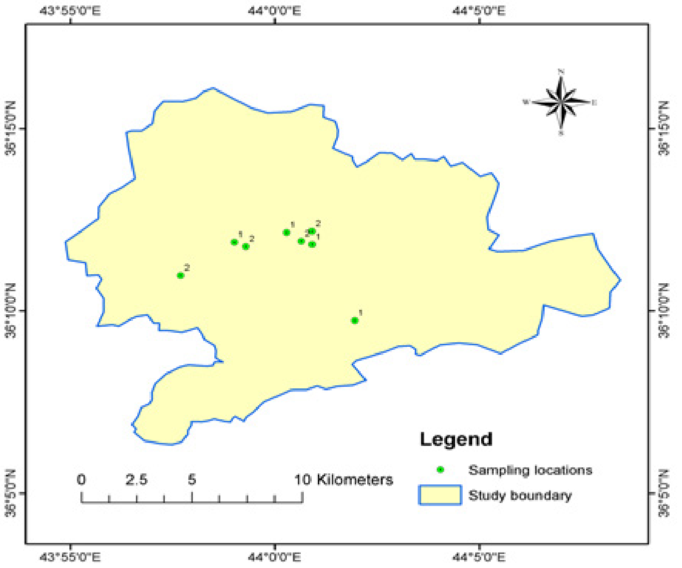

Figure 1: *Shows the study area and the locations of the sampling sites. Note, 1= Morus alba and 2= Melia azedarach L.*

Leaf relative water content (LRWC %)

To determine leaf fresh weight (FW), leaf samples were weighed as soon as the excess moisture was removed. Leaf samples were put with the cut end of the petiole immersed in distilled water in a 50 ml tube. The tubes were kept at 10°C in a fridge and for 24 (hours) the leaves were rehydrated. To calculate turgid weight (TW), leaves were weighed once again after being dried with paper towels. Following 48 hours of oven drying at 80°C at a consistent weight, the leaf samples' dry weight (DW) was determined by suinf below formula as documented by Arndt *et al.* (2015).

$$RWC\ (\%) = [(FW-DW) / (TW-DW)] \times 100$$

Where,
FW –fresh weight,
TW –turgid weight
DW –dry weight

Leaf pH

0.5 g of oven-dried samples (dry mass) were weighed and combined with 5 g of deionized water in a 10 mL centrifuge tube. The mass ratio of oven-dried leaf to water was 1:10. The mixtures were stirred at 250 rpm for 1 hour and subsequently separated into solid and liquid phases by sedimentation. The pH of the supernatant was determined using an accurate pH electrode (Chen *et al.*, 2022).

Total chlorophyll

The chlorophyll content of leaf samples was analyzed by using below equation following the methodology of Ali *et al.* (2021).

$$\text{Total chlorophyll (mg/gm)} = 20.2*(A649) + 8.02*(A645)*V/1000*FW$$

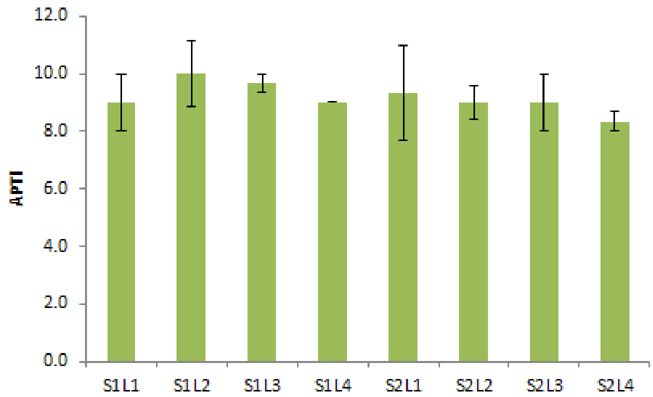

Figure 2: *APTI in leaves of the studied species*.

Data analyzing

All recorded data were subjected to SPSS computer analysis version 22 analysis. A factorial experiment system and a completely randomized block design (RBD) were used, and the Duncan test was employed for performing comparisons between each of the treatments. Correlation and regression analysis between biochemical analysis and APTI were done by using Excel Microsoft and SPSS. The Pearson correlation analysis illustrates individual associations between the APTI and different studied parameters, whereas the multivariate linear regression estimates APTI by leveraging the relationships within APTI and studied parameters The Stepwise regression (STWR) method was employed to determine the parameters and additional statistics of the multivariate linear regression model.

Results and Discussion

APTI can be defined as a synthetic index that combines the influences of LRWC, leaf extract pH, TC, and AAC to evaluate a species' tolerance to air pollution (Gautam and Shukla, 2020). The studied species exhibited no significant positive responses, with APTI values of 9.0 and 9.3 which are critical values for pollution and indicating in **Table** (2), indicating a sensitivity to air pollution as compared to species with higher APTI values (Achakzai *et al.* (2017), Watson and Bai (2021) and Zhang *et al.* (2020). The study results suggest that urban green development in Erbil city cannot exclusively incorporate with these identified species along roadsides and in heavily industrialized areas, based on their APTI index performances. The results of the research do not agree with those of Alotaibi *et al.* (2020) and Sharma *et al.* (2020). A study by Anake *et al.* (2019) found three tree species that are appropriate for green belt development, giving them useful additions to the list of plants for this arrangement in tropical Africa. The APTI values obtained for the examined species in the recent study may be employed to determine suitable future tree species for establishing green belts around motorways and in polluted regions. as recorded by Bala *et al.* (2022). In a study by Javanmard *et al.* (2020) *Morus alba* is identified as the most appropriate tree species for urban green spaces in arid environments, owing to its greater APTI values comparing to other species. According to Al-Healy and Ibrahim, (2022) research, the APTI values for all tested species ranged from 9 to 6, with *Callstemon viinalis* showing the highest APTI value among all roadside plants. *M. alba* in the Al-Tayaran region was equally air pollution-tolerant. In addition, five locations were designated for the collection of leaves from trees in Baghdad. The findings of the current study indicate that *Citrus aurantium* is susceptible to air pollution (AlObaidy and Rabee, 2018). While, A study by Salih *et al.* (2017) that the APTI values for both *Ficus sp.* and *Conocarpus sp.* were below 10 during the study period, indicating the susceptibility of both plants to air pollution. A comparison of the APTI values of *Pinus strobus* and *Cercis chinensis* revealed that the former had the highest values (Bui *et al.*, 2021). The most sensitive species, according to the APTI analysis of 54 trees, were *Mangifera indica* and *Tabebuia chrysantha-rosea*, with *Erythrina fusca* and *Spathodea campanulata* following closely behind. This highlights the significance of urban forests for environmental management in areas where air quality is a major concern (Correa-Ochoa *et al.*, 2022).

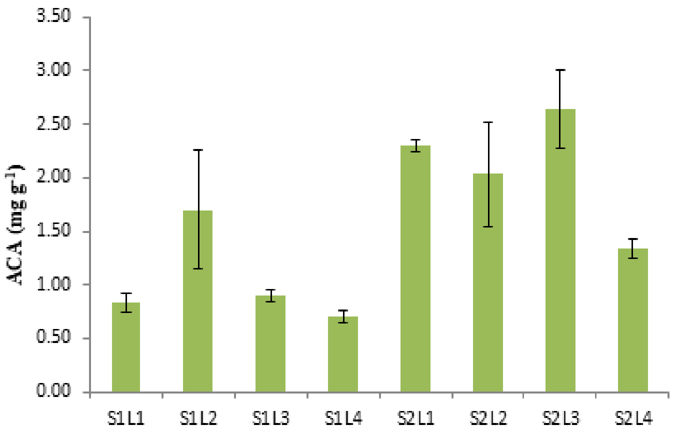

Figure 3: *Ascorbic acid in leaves of the studied species.*

Table 2 indicated that the ascorbic acid concentration showed a significant variation between the two tree species all over the four locations. Increased ascorbic acid levels have been found in the leaf samples of *M. azedarach* from location 3, measuring 2.63 mg g^{-1}, in comparison to less polluted areas. In addition, leaves were taken from site 3 (60 m ring road) had the highest ascorbic acid concentration, be followed by a less polluted location (Sami Abdulrahman Park), location 2 (100 m ring road) respectively (Figure 3). Achakzai, *et al.* (2017) it has been suggested that the elevated levels of ascorbic acid observed in the leaves of polluted locations may be an indication of a tolerance response on the part of tree species to the increasing levels of air pollution. as noted by Bharti *et al.* (2018). Palit *et al.* (2013) and Sanghi *et al.* (2015)

Table 2: *Evaluation of air pollution tolerance index (APTI) of studied Morus alba* L. *and Melia azedarach* L. *tree species grown in Erbil city.*

Species	LO no.	APTI	ACA mg g^{-1}	Total Chl. mg g^{-1}	Leaf pH	LRWC%
M. alba	L1	9.0 ±1.00a	0.83±0.09b	0.10±0.02 a	8.69 ±0.11a	82.67±9.94a
	L2	10.0±1.15a	1.70±0.56ab	0.08±0.01ab	7.50±0.09b	86.00±6.03a
	L3	9.7±0.33a	0.90±0.06b	0.06±0.01ab	6.62±0.30c	88.67±1.86a
	L4	9.0±0.00a	0.70±0.06b	0.10±0.01a	6.35±0.21c	87.67±0.88a
M. azedarach	L1	9.3±1.67a	2.30±0.06a	0.07±0.02ab	6.09±0.03c	76.33±15.17a
	L2	9.00.58a	2.03±0.49ab	0.04±0.01b	5.89±0.20c	76.33±1.20a
	L3	9.0±1.00a	2.63±0.37a	0.08±0.01ab	6.25±0.09c	72.33±4.70a
	L4	8.3±0.33a	1.33±0.09 ab	0.04±0.00b	6.22±0.04c	74.67±2.33a

LO no. = Location number (L1: Sami Abdulrhaman Park, as a location with less pollution, L2: 100 m ring road, L3: 60 m ring road and L4: 30 m ring road, MTS= moderate tolerant species, All data are mean values and standard deviation (M±SE) recognized that ascorbic acid functions as an effective antioxidant in protecting the stability of cell division and cell membranes in plants under adverse circumstances. Antioxidants perform this purpose by neutralizing harmful free radicals and reactive oxygen species generated by the photo-oxidation of SO_2 to SO_3, as documented by Aghajanzadeh *et al*. (2016). Moreover, ascorbic acid can mitigate the damaging effects of air pollution, so significantly contributing to the enhancement of plant tolerance to such environmental stressors. The results of the current study are consistent with previous research by Achakzai *et al*. (2017) and Bharti *et al*. (2018).

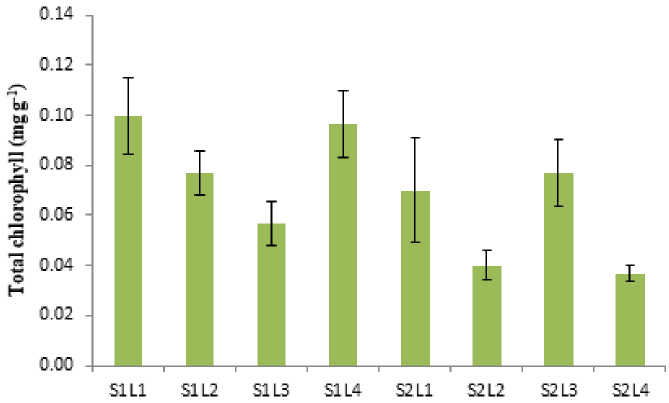

Figure 4: *Tota chlorophyll content in leaves of the studied species.*

A significant increase in total chlorophyll was obtained in *M. alba,* but a lower amount was recorded in *M. azedarach*. Plants with elevated chlorophyll levels in field circumstances typically show evidence of tolerance to air pollution (Kuddus *et al*., 2011). The total chlorophyll content in plants reflects photosynthetic activity, growth, and biomass development (Hamal and Chettri, 2017). Gillani *et al*, (2023) Stated that Chlorophyll pigmentation in leaves may be the best aspect to evaluate the healthiness of plants and eventually causes to estimation of yield. The chlorophyll content in leaves ranged from 0.7 mg g^{-1} to 0.10 mg g^{-1}, in less polluted sites and from 0.4 mg g^{-1}, to 0.10 mg g^{-1} at polluted sites (Table 2). In addition, *M. alba* was (0.10 mg g^{-1}) from the less polluted site and 30 m ring road, along with *M. azedarach* (0.08 mg g^{-1}) from the 60 m ring road, had the highest chlorophyll concentration. The reduction in chlorophyll content was noted in the tree species in the polluted location compared to the less polluted site (Figure 4). Typically, chlorophyll content reduces under pollution stress; however, the alteration in chlorophyll levels is also reliant upon the specific contaminants present in the environment Timilsina *et al*. (2022). Sulphur dioxide (SO_2) is an atmospheric pollutant; nevertheless, at lower amounts, it serves as an important nutrient for plants. As Bell and Mudd (1976) proposed that plant tolerance to (SO_2) may be associated with the synthesis or degradation of chlorophyll. Elevated concentrations become toxic, damaging chloroplast membranes and leading to chlorophyll breakdown (Hamal and Chettri, 2017). The current finding aligns with the results of (Yadav *et al*., 2020; Watson and Bai, 2021; Timilsina *et al*., 2022).

Table 3: *Pearson's correlation matrix between APTI along with biochemical parameters of plants collected from ring roadsides of Erbil city, Iraq.*

Parameters	APTI	ACA	Total CHL.	Leaf pH	LRWC
APTI	1				
ACA	.314	1			
Total CHL.	.187	-.142-	1		
Leaf pH	.138	-.318-	.426*	1	
					1
LRWC	.853**	-.186-	.286	.230	

**** Correlation is significant at $p \le 0.001$, **correlation is significant at $p \le 0.01$, *correlation is significant at $p \le 0.05$.*

At the experimental locations, the leaf pH of the studied trees, *M. alba*, attained a higher value of 7.50, while the leaf pH of *M. azedarach* reached a lower value of 6.25, the resulting data is presented in Table 2 and Table 3. Within the range of this study, the pH range of 5-8 is expressed by the both of species. According to Scholz and Reck (1977), the pH of the leaf decreases when acidic pollutants such as SO_2 and NO_2 are present. Furthermore, the decreased rate is lower in plant species that are tolerant of the pollution than it is in plant species that are sensitive to the pollution Scholz and Reck (1977). In a Scholz and Reck (1977), study, a significant decrease in pH value suggests the presence of sensitive species, while a minimal change in pH indicates the presence of tolerant species. In addition to influencing the rate of photosynthesis, the pH value reveals how plants perform when they are subjected to stress. The pH values in the current study ranged from 6.09 to 8.69 for *M. alba* and *M. azedarach* at the controlled location, and from 5.89 to 7.50 at the polluted site (Figure 5). The highest pH value was recorded for *M. alba* in location 1 while the pH values dropped for *M. azedarach* species along the 100 m ring road may be indicating more acidity compared to the less polluted location (Table 2). The optimal pH is conducive to normal cellular functions. Increasing pH levels enhance ascorbic acid concentration and improve the tolerance of plants to pollution. Conversely, the concentration of ascorbic acid diminishes at lower pH levels, resulting in less photosynthetic activity, hence indicating the susceptibility of plants to air pollution (Timilsina *et al*., 2022). The leave pH of plants in polluted areas has been documented in previous investigations from the city's polluted regions (Rawal *et al*., 2001; Bharti *et al*., 2018).

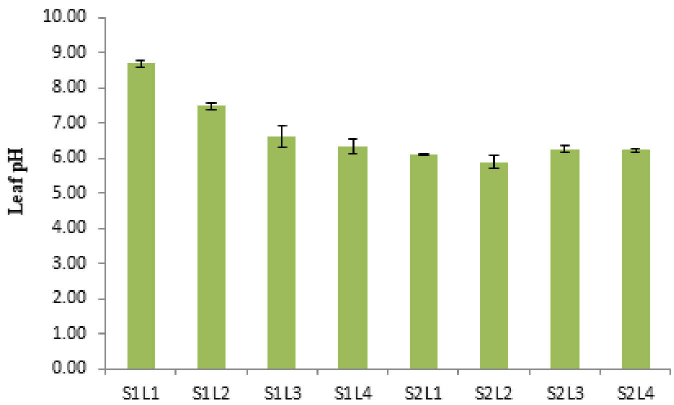

Figure 5: *Leaf extract pH in the leaves of the studied species*.

According to Bandara and Dissanayake (2021), to keep plants in a state of physiological a state of equilibrium the relative water content of leaves is important, when they are subjected to stress conditions such as air pollution. In the current investigation, the LRWC ranged from 76.33 percent to 88.67 percent. *M. alba* was revealed the highest percentage of relative water content, whereas *M. azedarach* was found to have the lowest percentage of water content (Figure 6). Earlier research by Mukhopadhyay *et al*. (2021) revealed that the percentage of LRWC ranged from 60 to 70 percent, depending on the type of plant being studied respectively. According to the findings of the research carried out by Bala *et al*. (2022), the majority of the observed plant species had LRWC values that fall somewhere in the region of 60 to 80 percent. According to Bala *et al*. (2022), the plant species with the highest LRWC was discovered to be *M. azedarach*,, followed by *M. alba*. The plant sustains elevated hydration levels and turgor pressure despite unfavourable conditions. This suggests that the plant is successfully managing its water balance, therefore improving its capacity to sustain critical physiological processes, including photosynthesis, during periods of stress. Bandara and Dissanayake (2021).

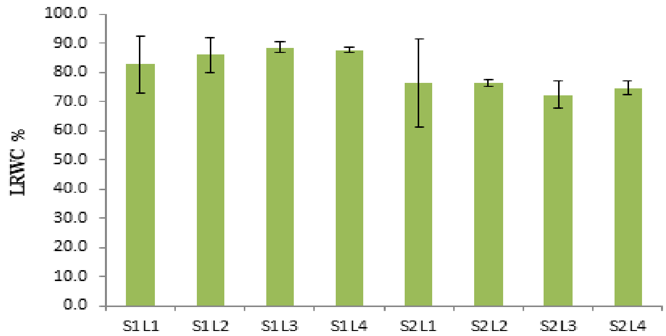

Figure 6: *Leaf relative water content in leaves of the stuided species.*

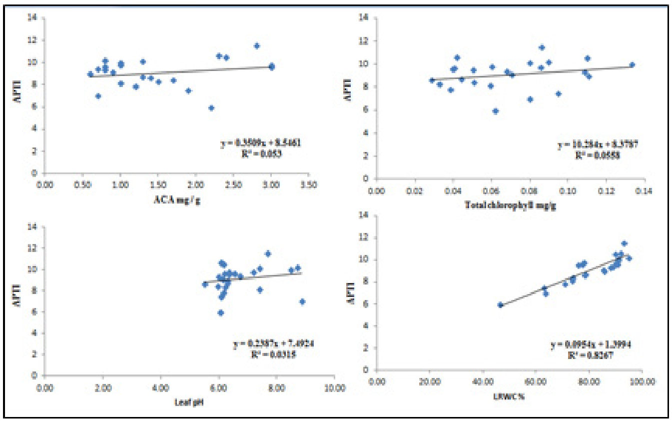

Figure 7: *Simple linear regression developed models of APTI values with individual measured parameters of the studied species.*

Statistical study of biochemical parameters and APTI

Statistical analysis was conducted using SPSS and Excel, with results presented in Table 2. A substantial relationship was obtained between APTI and LRWC, with $R^2 = 0.8267$. Furthermore, no positive correlation was observed between APTI and leaf pH, total chlorophyll, and ascorbic acid ($R^2 = 0.03$; $R^2 = 0.05$; $R^2 = 0.05$) (Figure 7) (Table 3). This correlation suggests that as air pollution increases, the relative water content likewise rises to mitigate the stressful conditions (Gautam and Shukla, 2020). The stepwise variable selection regression approach (SVSRT), an adaptation of the forward-selection method, follows this procedure: a variable has been integrated into the model, and the significance of its involvement in predicting the dependent variable is assessed using the partial F-test. If a variable significantly contributes, it is incorporated into the model; otherwise, it is excluded. The SVSRT was performed during all fitting stages. This analysis expected the following sort of linear relationship:

$$y = -0.903996 + 0.667569*x_1 + 0.110715*x_3 + 0.101901*x_4$$

Where, Y is air pollution tolerance index (APTI), $X_1,\ldots,X_n$ are parameter vectors (independent variables) corresponding to measured parameter values, $\beta_{1=}$0.667569, $\beta_{1=}$0.110715 and β_3=0.101901) represent model coefficients. The P-value in the ANOVA table is below 0.05, indicating a statistically significant interaction between the variables at the 95.0% confidence level. The R-Squared value demonstrates that the fitted model accounts for 99.84% of the variability in y. The corrected R-squared statistic, more appropriate for comparing models with varying quantities of independent variables, is 99.816%. The standard error of the estimate indicates that the standard deviation of the residuals is 0.0534599. This value can be utilized to establish prediction restrictions for unexpected observations. The mean absolute error (MAE) of 0.0321758 represents the average intensity of the residuals. The Durbin-Watson (DW) statistic evaluates the residuals to ascertain the presence of any significant association related to their sequential arrangement in the data file. The P-value exceeds 0.05, indicating an absence of serial autocorrelation in the residuals at the 95.0% confidence level. To assess the potential for model simplification, observe that the greatest P-value among the independent variables is 0.0000, attributed to x3. The P-value, being less than 0.05, indicates statistical significance at the 95.0% confidence level. Therefore, it is advisable not to eliminate any variables from the model.

Conclusions and Recommendations

In urban forest ecosystem, the tolerance of a species needs to be evaluated from one essential perspective: its ability to tolerate air pollution. Biochemical parameters were investigated in the present study. It was found that *M. alba* had the highest APTI, Total chlorophyll, Leaf extract pH, relative water content, with lower values of ascorbic acid. This study assesses APTI at the leaf level, and additional research is required to examine the impact of tree morphology on tolerance efficiency. The limitation of the current study is the necessity for further investigation of additional tree species, besides the identified species. Furthermore, incorporating two additional ring roads (120 m and 150 m) in Erbil city may enhance the sustainability of future urban plantations.

Acknowledgements

We would like to extend my appreciation to Professor Tariq G. Salih for clarifying regression analysis. A special thanks to my supervisor Professor Dr. Kawa A. Ali, Mrs. Rahela S. Qader and the Forestry Department of the College of Agricultural Engineering Sciences for providing a space for the researchers to conduct an investigation. The work is funded and supported by the University of Salahaddin- Erbil.

Novelty Statement

The research and experiment on the topic are novel in the field of forestry and urban forest in Erbil city. The research also presents a new model for APTI that can be utilized to reduce time and costs for future effort.

Author's Contribution

Halmat Abubakr Sabr: Investigation, conceptualization, preparation for the writing-original draft, Data gathering, Methodology, Data analysis, References and citation, Software and Writing.
Kawa Abdulkareem Ali: Supervision, Validation, review and editing. This research is a part of PhD study.

Generative AI or AI assisted technology statement
The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of Interest
There is no conflict of interest.

References

Achakzai, K., S. Khalid, M. Adrees, A. Bibi, S. Ali, R. Nawaz and M. Rizwan. 2017. Air pollution tolerance index of plants around brick kilns in Rawalpindi, Pakistan. J. Evni. Manag., 190: 252-258. https://doi.org/10.1016/j.jenvman.2016.12.072

Aghjanzadeh, T., M.J. Hawkesford and L.J. De Kok. 2016. Atmospheric H2S and SO2 as sulfur sources for Brassica juncea and Brassica rapa: Regulation of sulfur uptake and assimilation. Envi Exper. Bot., 124: 1-10. https://doi.org/10.1016/j.envexpbot.2015.12.001

Akram, N.A., F. Shafiq and M. Ashraf. 2017. Ascorbic acid-a potential oxidant scavenger and its role in plant development and abiotic stress tolerance. Fron. plan. Sci., 8: 613. https://doi.org/10.3389/fpls.2017.00613

Aleadelat, W. and K. Ksaibati. 2018. A comprehensive approach for quantifying environmental costs associated with unpaved roads dust. J. Environ. Econ. Poli., 7(2): 130-144. https://doi.org/10.1080/21606544.2017.1374214.

Ali, K.A., S.S. Noraldeen and A.A. Yaseen. 2021. An evaluation study for chlorophyll estimation techniques. Sar. J. Agric., 37(4): 1458-1465. https://dx.doi.org/10.17582/journal.sja/2021/37.4.1458.1465

Ali, J., Malik, S.U. Ashraf, M.I. Zhongkui, J.Z. Husnain and S. Gulzar. 2023. Exploring the potential of carbon sequestration in sub-tropical pine forest ecosystem: A case study in District Kurram, Pakistan. Sar. J. Agric., 39(3): 647-654. https://dx.doi.org/10.17582/journal.sja/2023/39.3.647.654

Al-Healy, R. and I. Ibrahim. 2022. Assessment of Tolerance Levels to Air Pollution for Some Species of Trees and Shrubs Growing on Roadsides in Western Mosul City. J. Edu. Sci., 31(2): pp.10-0. https://dx.doi.org/10.33899/edusj.2022.132140.1198

AlObaidy, W.A. and A.M. Rabee. 2018. Use *Citrus aurantium* plant as bio-indicator of air pollution in Baghdad city. Ira. J. of Sci., pp. 824-831.

Alotaibi, M.D., B.H. Alharbi, M.A. Al-Shamsi, T.S. Alshahrani, A.A. Al-Namazi, S.F. Alharbi and Y. Qian. 2020. Assessing the response of five tree species to air pollution in Riyadh City, Saudi Arabia, for potential green belt application. Environ. Sci. Pollu. Res., 27: 29156-29170. https://doi.org/10.1007/s11356-020-09226-w

Anake, W.U., J.E. Eimanehi, M. Javal, P. Simek and C.A. Omonhinmin. 2019. Evaluation of air pollution tolerance index and anticipated performance index of selected plant species. Indones. J. Chem., 19(1): 239-244. https://doi.org/10.22146/ijc.35270

Arndt, S.K., A. Irawan and G.J. Sanders. 2015. Apoplastic water fraction and rehydration techniques introduce significant errors in measurements of relative water content and osmotic potential in plant leaves. Physio. Planta., 155(4): 355-368. https://doi.org/10.1111/ppl.12380

Bala, N., Y.B., Pakade and J.K. Katnoria .2022. Assessment of air pollution tolerance index and anticipated performance index of a few local plant species available at the roadside for mitigation of air pollution and green belt development. Air Qual. Atmos. Heal., 15(12): 2269-2281. https://doi.org/10.1007/s11869-022-01251-7

Bandara, W.A.R.T.W and C.T.M. Dissanayake. 2021. Most tolerant roadside tree species for urban settings in humid tropics based on Air Pollution Tolerance Index. Urban Clim., 37: 100848. https://doi.org/10.1016/j.uclim.2021.100848

Batcher, M.S. 2008. Element stewardship abstract for *Melia azedarach*. The Nature Conservancy. Viewed 22 February.

Bell, J.N.B. and Mudd, C.H., 1976. Sulphur dioxide resistance in plants: A case study of *Lolium perenne*. New Phytolog., 83: 627-643. https://doi.org/10.1111/j.1469-8137.1979.tb02295.x

Bharti, S.K., A. Trivedi and N. Kumar. 2018. Air pollution tolerance index of plants growing near an industrial site. Urb. Clim., 24: 820-829. https://doi.org/10.1016/j.uclim.2017.10.007

Bui, H.T., U. Odsuren, K.J. Kwon, S.Y. Kim, J.C. Yang, N.R. Jeong and B.J. Park. 2021. Assessment of air pollution tolerance and particulate matter accumulation of 11 woody plant species. Atmosp., 12(8): 1067. https://doi.org/10.3390/atmos12081067

Chavan, B.L. and N.S. Sonwane. 2012. Anticipated Performance Index (API) of some tree species grown in Aurangabad city. Int. J. Environ. Rehab. Conser., 3(2): 9-13.

Chen, J., S. Liu, Y. Hou, Y. Luo and W. Han. 2022. Determination of Leaf pH without Grinding the Sample: Is It Closer to the Reality? Fore., 13(10): 1640. https://doi.org/10.3390/f13101640

Dzierżanowski, K., R. Popek, H. Gawrońska, A. Sæbo and S.W. Gawroński. 2011. Deposition of particulate matter of different size fractions on leaf surfaces and in waxes of urban forest species. Inter. J. phytore., 13(10): 1037-1046. https://doi.org/10.1080/15226514.2011.552929

Gautam, P. and A.K. Shukla. 2020. Identification of air pollution index of certain local available plants at industrial area on the basis of air pollution tolerance index. IOP Confer. Seri.: Mater. Sci. Engin. (Vol. 955, No. 1, p. 012081). IOP Publish. http://dx.doi.org/doi:10.1088/1757-899X/955/1/012081

Gillani, S.S.M., M.N. Tahir, A. Anwar, S.I. Ul-Haq, M. Awais, M. Iqbal and M.A. Khan. 2023. Real time estimation of wheat chlorophyll content retrieves from Landsat 8 imagery under rainfed condition. http://dx.doi.org/10.17582/journal.sja/2023.39.1.147.155

Hamal, J.P. and M.K. Chettri. 2017. Air pollution tolerance index of some selected gymnosperm species along the road side of Kathmandu Valley, Nepal. Ecoprint: Int. J. Eco., 24: 13-19. https://doi.org/10.3126/eco.v24i0.20642

Hassan, I., B. Rehman, M. Amir, F. Ali, S. Ilahi and A. Ali. 2020. Development of electrostatic particulate collection system for agricultural biomass based energy applications. Sar. J. Agric., 36(3): 742-747. https://dx.doi.org/10.17582/journal.sja/2020/36.3.742.747

Janhäll, S. 2015. Review on urban vegetation and particle air pollution–Deposition and dispersion. Atmos. Envi., 105: 130-137. https://doi.org/10.1016/j.atmosenv.2015.01.052

Janick, J. and R.E. Paull. (Eds.). 2008. The encyclopedia of fruit & nuts. CABI.

Javanmard, Z., M.T. Kouchaksaraei, S.M. Hosseini and A.K. Pandey. 2020. Assessment of anticipated performance index of some deciduous plant species under dust air pollution. Environ. Sci. Pollu. Res., 27: 38987-38994. https://doi.org/10.1007/s11356-020-09957-w

Kaur, M. and A.K. Nagpal. 2017. Evaluation of air pollution tolerance index and anticipated performance index of plants and their application in development of green space along the urban areas. Environ. Sci. Pollu. Res., 24: 18881-18895. https://doi.org/10.1007/s11356-017-9500-9

Kuddus, M., R. Kumari and P.W. Ramteke. 2011. Studies on air pollution tolerance of selected plants in Allahabad city, India. J. Environ. Res. Mange., 2(3): 042-046.

Miria, A. and A.B. Khan. 2013. Air pollution tolerance index and carbon storage of select urban trees-a comparative study. Int. J. Appl. Res. Stud. (IJARS), 2(5): 1-7.

Mukhopadhyay, S., R. Dutta and A. Dhara. 2021. Assessment of air pollution tolerance index of *Murraya paniculata* (L.) Jack in Kolkata metro city, West Bengal, India. Urb. Cli., 39: 100977. https://doi.org/10.1016/j.uclim.2021.100977

Palit, D., Kar, D., Misra, P and A. Banerjee. 2013. Assessment of air quality using several bio monitors of selected sites of Durgapur, Burdwan district by air pollution tolerance index approach. Ind. J. Sci. Res., 4(1): 149-152.

Rai, P.K. 2016. Impacts of particulate matter pollution on plants: Implications for environmental biomonitoring. Ecotoxi. Environ. Saf., 129: 120-136. https://doi.org/10.1016/j.ecoenv.2016.03.012

Rahman, M. and S. Islam. 2021. Studies on Food, Health and Environmental Perspectives In Mulberry (Morus Spp.) A Review. J. Bio. Sci., 29: 163–179. https://doi.org/10.3329/jbs.v29i0.54832

Rawal, D.S., J.S. Sijapati, N. Rana and T.M. Pradhananga. 2001. Air pollution tolerance index of some tree species of Kathmandu Valley. Nepal J. Sci. Tech., 3(1).

Rasool, A., S. Muhammad, M. Tayyab, A. Bajwa, A. Majeed, M.B. Munam, S. Faisal, A. Khairdin, S. Khalid, H.K. Hanif and S.M., Malik. 2025. Ecological evaluation of dominant roadside plants through APTI and API for sustainable green belt development in cosmopolitan city (Lahore) of Pakistan. Sci. Repor., 15(1): p.10496. https://doi.org/10.1038/s41598-024-76882-0

Salih, P., M. Mahdi and B.M. Hassan. 2017. Evaluation of Air Pollution Tolerance Index (APTI) by two species of terrestrial plants in some stations within Babylon Province, Iraq. B. S. J., 14(2): p.15. https://doi.org/10.21123/bsj.2017.14.2.0349

Sanghi, S.B., C. Sharma and S.K. Sanghi. 2015. Comparison of APTI values of some medicinal plants of industrial areas and Ratapani wild life sanctuary in Raisen district of Madhya Pradesh. Int. J. Pharm. Life Sci., 6(1: 4157-4160.

Scholz, F. and S. Reck. 1977. Effects of acids on forest trees as measured by titration in vitro, inheritance of buffering capacity in *Picea abies*. Water Air Soil Pollut., 8: 41-45 https://doi.

org/10.1007/BF00156723

Singh, S.K and D.N. Rao. 1983. Evaluation of the plants for their tolerance to air pollution Proc. Symp on Air Pollution control held at IIT, Delhi. 218-224.

Sharma, A., S.K. Bhardwaj, L.R. Panda and A. Sharma. 2020. Evaluation of anticipated performance index of plant species for green belt development to mitigate air pollution. Int. J. Bio-re. and St. Man., 11(6): pp.536-541. https://doi.org/10.23910/1.2020.2148

Shahrukh, S., S.A. Hossain, M.N. Huda, M. Moniruzzaman, M.M. Islam, M.A.A. Shaikh and M.E. Hossain. 2023. Air pollution tolerance, anticipated performance, and metal accumulation indices of four evergreen tree species in Dhaka, Bangladesh. C. P. Bio., 35: p.100296. https://doi.org/10.1016/j.cpb.2023.100296

Supriya, K., R. Chauhan, R.K. Aggarwal. 2025. Environmental Assessment of Plant Species Using APTI and API along NH-07 in Himachal Pradesh, Ind. Environ. Sci., 4(1): p.35. https://doi.org/10.5281/zenodo.14698351

Timilsina, S., S. Shakya, S. Chaudhary, G. Thapa Magar and N. Narayan Munankarmi. 2022. Evaluation of air pollution tolerance index (APTI) of plants growing alongside inner ring road of Kathmandu, Nepal. Int. J. of Environ. Stud., 79(4): 698-713. https://doi.org/10.1080/00207233.2021.1946346

Tripathi, D.P and A.K. Nema. 2023. Seasonal variation of biochemical parameters and air pollution tolerance index (APTI) of selected plant species in Delhi city and detailed meta-analysis from Indian metropolitan cities. Atm. Environ., 309: p.119862. https://doi.org/10.1016/j.atmosenv.2023.119862

Watson, A.S and R.S. Bai. 2021. Phytoremediation for urban landscaping and air pollution control a case study in Trivandrum city, Kerala, India. Environ. Sci. Pollu. Res., 28(8): 9979-9990. https://doi.org/10.1007/s11356-020-11131-1

Yadav, R., M.S. Bhatti, S.K. Kansal, L. Das, V. Gilhotra, A. Sugha and T.K. Mandal. 2020. Comparison of ambient air pollution levels of Amritsar during foggy conditions with that of five major north Indian cities: multivariate analysis and air mass back trajectories. SN Appl. Sci., 2: 1-11. https://doi.org/10.1007/s42452-020-03569-2

Zhang, W., Y. Zhang, J. Gong, B. Yang, Z. Zhang, B. Wang and K. Yue. 2020. Comparison of the suitability of plant species for greenbelt construction based on particulate matter capture capacity, air pollution tolerance index, and antioxidant system. Envi. Pollu., 263: 114615. https://doi.org/10.1016/j.envpol.2020.114615