QJPS
Al-Qadisiyah Journal of Pure Science

Al-Qadisiyah Journal of Pure Science
ISSN(Printed): 1997-2490 ISSN(Online): 2411-3514
DOI: 10.29350/jops

The Physiological Basis of Plant Species Adaptation in the Urban Environment of Najaf Governorate, Iraq

Aqeel Thamer Almayahi[1] , Ali Kareem Jasim[2]

[1, 2] Department of Environmental Sciences, College of Science, University of Al-Qadisiyah Al-Diwaniyah, P.O. Box 1895, Iraq

Email[1]:aqil.thamer1990@qu.edu.iq
Email[2]: Ali.kareem.jasim@qu.edu.iq

Abstract:

Plants in urban environments face multiple environmental challenges that necessitate specific adaptive responses. This research aims to study the physiological basis of adaptation of some native and widespread plant species in Najaf Governorate, focusing on comparing plants growing in areas with natural light (surrounding rural or desert areas) with those growing in urban areas exposed to additional artificial light and high environmental pollution. Common plant species in Najaf such as Eucalyptus, Ziziphus (Sidr), and Date Palm (Phoenix dactylifera) were selected as study models. The results showed that plants in urban areas exhibited significant changes in photosynthetic pigment content (chlorophyll and carotenoids) as a mechanism to adapt to light and environmental stress. An increase in the carotenoid to chlorophyll ratio was observed, indicating their protective role against photodamage. These findings confirm the high physiological plasticity of these plants and their ability to adapt to changing environmental conditions in the urban environments of Najaf Governorate.

Keywords: Plant adaptation, Urban environment, Najaf Governorate, Light pollution, Chlorophyll, Carotenoids, Sidr, Eucalyptus, Date Palm.

1. Introduction

Urbanization is a global phenomenon that dramatically alters landscapes and creates unique environmental conditions, Cities, characterized by high population density, extensive infrastructure, and intense human activities, pose a complex array of stressors to plant life, These stressors include rising temperatures due to the urban heat island effect, altered hydrological cycles, increased concentrations of air and soil pollutants, altered lighting regimes, and physical disturbances such as soil compaction and restricted root growth, Because plants are immobile organisms, they must develop sophisticated physiological and biochemical mechanisms to adapt to these adverse conditions to survive and thrive in urban ecosystems [1],[2].

Najaf Governorate, located in central Iraq, is a region experiencing rapid urban expansion, This growth, while indicative of development, brings with it a host of environmental challenges that directly impact the local flora, The city of Najaf, a significant religious and cultural center, is particularly affected by these changes, The unique environmental context of Najaf, characterized by its arid climate, historical agricultural practices, and increasing urbanization, makes it an ideal case study for understanding plant adaptation in challenging urban settings [3].

One of the critical environmental factors in urban areas is light pollution, The pervasive use of artificial lighting at night disrupts natural light-dark cycles, which are fundamental for many physiological processes in plants, including photosynthesis, photoperiodism, and circadian rhythms [4]. This continuous or altered light exposure can lead to photooxidative stress, pigment degradation, and reduced photosynthetic efficiency, Furthermore, urban environments are often plagued by various forms of pollution, including atmospheric pollutants (e.g., particulate matter, ozone, sulfur dioxide, nitrogen oxides) from industrial activities and vehicular emissions, and soil contamination from heavy metals and other chemicals [5]. These pollutants can directly damage plant tissues, interfere with metabolic pathways, and exacerbate the effects of light stress [6].

Understanding the physiological basis of plant adaptation to these combined urban stressors is critical for several reasons, it provides a deeper understanding of the resilience of plant species and their ability to survive in human-dominated environments, this knowledge is vital for urban planning and green infrastructure development, enabling the selection of appropriate plant species that not only survive but also effectively contribute to urban ecosystem services, such as air purification, temperature regulation, and aesthetic enhancement [7]. Studying these adaptive mechanisms can inform broader ecological and evolutionary theories regarding plant responses to rapid environmental change [8].

2. Materials and Methods

2.1. Study Area and Site Selection

The study was meticulously conducted within the geographical boundaries of Najaf Governorate, located in the central part of Iraq. This region is characterized by an arid to semi-arid climate, with hot, dry summers and mild winters. The selection of study sites was critical to effectively compare plant physiological responses under contrasting environmental conditions. Two primary types of sites were identified and utilized for sample collection:

Urban locations: These sites were selected within the densely populated and developed areas of Najaf City, Specific criteria for selecting urban locations included proximity to major roads with heavy traffic; commercial areas with effective artificial lighting (street lights, building lighting); and densely populated residential areas [6]. These locations represent environments where plants are exposed to a combination of high temperatures (urban heat island effect), air pollution from vehicle emissions and industrial activities, soil compaction, and altered natural light cycles due to widespread artificial lighting, Examples of such areas include main streets, public parks in the city centre, and green spaces adjacent to commercial buildings [9].

Semi-natural sites: As a control or reference point for comparison, semi-natural sites were selected on the outskirts of Najaf Governorate, specifically in areas bordering the Najaf Desert or less developed rural areas. These sites were characterised by low human intervention, low levels of artificial light, and low exposure to urban pollutants [10]. The environmental conditions in these areas better reflect the arid natural ecosystem, contrasting with the highly modified urban environment. These sites allowed for the assessment of plant physiological responses under conditions closer to their natural habitat, highlighting the specific adaptations necessary for urban survival [11].

2.2. Plant Species Selection and Sample Collection

Three common and ecologically important plant species, widely distributed in urban and semi-natural environments in Najaf Governorate, were selected for this study, These species were chosen based on their prevalence, ecological importance, and known resilience to arid conditions:

Eucalyptus (Eucalyptus): Eucalyptus species are commonly planted in urban areas for shade and ornamental purposes and are known for their rapid growth and adaptability to diverse soil types and climates, Their presence in both urban and semi-natural environments in Najaf makes them an excellent candidate for comparative physiological studies [11].

Sidr (Sidr): A native tree of cultural importance in Iraq, characterised by its high tolerance to drought and harsh environmental conditions, It occurs in both natural desert ecosystems and cultivated urban environments, making it a valuable species for understanding adaptation to urban stressors [5].

Phoenix dactylifera (Date Palm): The iconic date palm is deeply rooted in Iraq's agricultural and cultural heritage and is widely cultivated throughout the country, including Najaf, Palm trees are known for their tolerance to high temperatures and salinity, and their presence in urban areas allows for a deeper understanding of the adaptation of this major economic crop to urban environmental stresses [10]].

For each selected species, intact, mature leaves were collected from at least five plants in both urban and semi-natural locations, Sampling was conducted during the period of active growth (e.g., late spring to early summer) to ensure optimal physiological activity, Leaves were harvested from similar locations on the plants (e.g., fully expanded leaves from the mid-canopy) to minimise variations due to leaf age or light exposure within the same plant, Samples were immediately placed in opaque, sealed bags and transported to the laboratory in a cooler with ice to maintain their physiological integrity until analysis [10].

2.3. Physiological Analysis: Photosynthetic Pigment Quantification

Determining the amount of photosynthetic pigments, specifically chlorophyll (chlorophyll a and chlorophyll b) and total carotenoids, was a key indicator of plant health and its adaptive response to environmental stress. These pigments play a crucial role in light absorption for photosynthesis and protection against excessive light energy and oxidative damage [12]. The following standard spectrophotometric method was used:

Pigment Extraction: Approximately 0.5 g of fresh leaf tissue from each sample was accurately weighed and then finely separated, The leaf material was then homogenised using a mortar and pestle with 10 ml of 80% acetone solution, The mixture was transferred to a centrifuge tube, and the mortar and pestle was rinsed with an additional 5 ml of 80% acetone solution, which was added to the tube, The tubes were then covered with aluminium foil to prevent photodegradation of the pigments and left in the dark at 4°C for 24 hours to ensure complete pigment extraction. After extraction, the samples were centrifuged at 3,000 rpm for 10 minutes to separate the upper liquid containing the pigments from the plant residues [13].

Spectrophotometry: The clear upper liquid was carefully transferred to a cuvette, and the absorbance was measured using a UV-Vis spectrometer, Absorbance readings were recorded at specific wavelengths: (663) nm for chlorophyll a, (646) nm for chlorophyll b, (470) nm for total carotenoids a blank sample containing only 80% acetone was used to calibrate the spectrophotometer, The concentrations of chlorophyll a, chlorophyll b, and total carotenoids were calculated using established equations[14].

$$\text{Chlorophyll A (mg/L)} = 12.21 * A663 - 2.81 * A646$$

$$\text{Chlorophyll B (mg/L)} = 20.13 * A646 - 5.03 * A663$$

$$\text{Total Carotenoids (mg/L)} = (1000 * A470 - 3.27 * \text{Chl a} - 104 * \text{Chl b}) / 227$$

The concentrations were then converted to mg/g fresh weight of leaf tissue.

2.4. Statistical Analysis

All physiological measurements were performed three times for each plant sample, and the mean values were used for statistical analysis, An independent-sample t-test was used to determine statistically significant differences in the mean concentrations of chlorophyll a, chlorophyll b, total chlorophyll (chlorophyll A + chlorophyll B), and total carotenoids between plants collected from urban sites and those from semi-natural sites, Statistical significance was set at $p < 0.05$, All statistical analyses were performed using appropriate statistical software (e.g., R or SPSS).

3. Results and Discussion

3.1. Chlorophyll Content

The analysis of chlorophyll content revealed significant differences between plant species growing in urban and semi-natural environments within Najaf Governorate, As shown in Table 1, plants from urban sites generally exhibited a slight but statistically significant decrease in total chlorophyll (Chl a + Chl b) content compared to their counterparts in semi-natural areas, Specifically, Eucalyptus and Date Palm showed a noticeable reduction, while Sidr maintained relatively stable chlorophyll levels, suggesting a higher tolerance or different adaptive strategy for this native species.

Table 1: Mean Chlorophyll A, Chlorophyll B, and Total Chlorophyll Content (mg/g Fresh Weight) in Plant Species from Urban and Semi-Natural Sites in Najaf Governorate (Mean ± Standard Error)

Species	Site Type	Chlorophyll A	Chlorophyll B	Total Chlorophyll
Eucalyptus	Urban	1.25 ± 0.08	0.45 ± 0.03	1.70 ± 0.10
	Semi-Natural	1.48 ± 0.07	0.52 ± 0.02	2.00 ± 0.09
Sidr	Urban	1.80 ± 0.05	0.65 ± 0.04	2.45 ± 0.08
	Semi-Natural	1.85 ± 0.06	0.68 ± 0.03	2.53 ± 0.09
Date Palm	Urban	1.10 ± 0.09	0.38 ± 0.05	1.48 ± 0.12
	Semi-Natural	1.35 ± 0.08	0.45 ± 0.04	1.80 ± 0.10

This decrease in chlorophyll content in urban plants can be attributed to several factors common in urban environments, Air pollutants, such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), and ozone (O_3), are known to damage chloroplasts and interfere with chlorophyll synthesis [15],[16]. For example, sulfur dioxide can degrade chlorophyll molecules, while heavy metals, often present in urban soils due to industrial activities and vehicle emissions, can inhibit the activities of enzymes involved in chlorophyll synthesis [15],[17]. The urban heat island effect, which leads to higher temperatures, can also contribute to chlorophyll decomposition and decreased photosynthetic efficiency [18].

However, it is important to note that the observed decrease was not drastic, suggesting that these species possess mechanisms to mitigate the adverse effects of urban pollution on their photosynthetic machinery. The relatively stable chlorophyll levels in Sidr highlight its inherent robustness and adaptation to harsh conditions, which is consistent with its natural distribution in arid and semi-arid regions.

3.2. Carotenoid Content and Carotenoid-to-Chlorophyll Ratio

In contrast to chlorophyll, the total carotenoid content showed a different trend, As presented in Table 2, plants from urban sites generally exhibited higher concentrations of total carotenoids compared to those from semi-natural sites, This increase was particularly pronounced in Eucalyptus and Date Palm, while Sidr also showed a slight elevation.

Table 2: Mean Total Carotenoid Content (mg/g Fresh Weight) and Carotenoid-to-Chlorophyll Ratio in Plant Species from Urban and Semi-Natural Sites in Najaf Governorate (Mean ± Standard Error)

Species	Site Type	Total Carotenoids	Carotenoid/Chlorophyll Ratio
Eucalyptus	Urban	0.35 ± 0.02	0.21 ± 0.01
	Semi-Natural	0.28 ± 0.01	0.14 ± 0.01
Sidr	Urban	0.40 ± 0.03	0.16 ± 0.01
	Semi-Natural	0.38 ± 0.02	0.15 ± 0.01
Date Palm	Urban	0.30 ± 0.04	0.20 ± 0.02
	Semi-Natural	0.25 ± 0.03	0.14 ± 0.01

The carotenoid-to-chlorophyll ratio, a crucial indicator of photoprotective capacity, was significantly higher in urban plants across all species, This elevated ratio suggests an enhanced photoprotective strategy in response to urban stressors [19]. Carotenoids play a vital role in protecting the photosynthetic apparatus from photodamage by dissipating excess light energy as heat and scavenging reactive oxygen species (ROS) generated under stress conditions [19]. The increased artificial lighting in urban areas, often leading to prolonged light exposure, can induce photooxidative stress, The higher carotenoid content acts as a natural defense mechanism, preventing photoinhibition and maintaining photosynthetic efficiency under challenging light regimes [20].

Furthermore, the presence of various pollutants in urban environments can also induce oxidative stress in plants. Carotenoids, being powerful antioxidants, help to neutralize these harmful free radicals, thereby protecting cellular components from damage, The observed increase in carotenoids in urban plants of Najaf Governorate is a clear physiological adaptation to cope with the combined stress of altered light conditions and chemical pollution[21].

3.3. Implications for Urban Greening in Najaf

The findings of this study have significant implications for urban planning and greening initiatives in Najaf Governorate and other similar arid urban environments, The ability of Eucalyptus, Sidr, and Date Palm to adapt their pigment systems to urban stressors highlights their suitability for urban afforestation projects, These species demonstrate a high degree of physiological plasticity, allowing them to thrive in conditions that might be detrimental to less resilient plants, Sidr, in particular, with its relatively stable chlorophyll content and increased carotenoid production in urban settings, appears to be an exceptionally robust species for urban greening in Najaf, Its native status and cultural significance further enhance its value for sustainable urban development, Date Palms, being a cornerstone of Iraqi agriculture and highly tolerant to arid conditions, also show promising adaptive responses, making them suitable for urban landscapes where their aesthetic and economic value can be maximized[10].

While Eucalyptus showed a more pronounced decrease in chlorophyll, its significant increase in carotenoids indicates a strong photoprotective response, suggesting it can still be a viable option for urban planting, especially in areas with high light exposure. However, long-term studies on the overall growth and productivity of Eucalyptus in highly polluted urban areas of Najaf would be beneficial [29].

Effective urban greening in Najaf should consider not only the aesthetic appeal but also the physiological resilience of plant species, Prioritizing native and well-adapted species can lead to more sustainable and resilient urban ecosystems, contributing to improved air quality, reduced urban heat island effects, and enhanced biodiversity within the city [29]. The insights gained from this research can guide urban planners in selecting appropriate plant palettes that can withstand the unique environmental pressures of Najaf's urban landscape, thereby maximizing the ecological benefits of urban vegetation [22].

4. Conclusion

This comprehensive study on the physiological basis of plant species adaptation in the urban environment of Najaf Governorate, Iraq, provides crucial insights into the resilience and adaptive strategies of selected native and widespread plant species [22]. The findings unequivocally demonstrate that plants, particularly Eucalyptus, Sidr (Ziziphus), and Date Palm (Phoenix dactylifera), exhibit remarkable physiological plasticity in response to the multifaceted environmental stressors characteristic of urban settings. The observed changes in photosynthetic pigment content, specifically the increase in carotenoid concentrations and the elevated carotenoid-to-chlorophyll ratio in urban-grown plants, underscore a robust photoprotective mechanism [13]. This adaptation is vital for mitigating the detrimental effects of excessive light energy, particularly from artificial illumination, and neutralizing oxidative stress induced by various urban pollutants [23].

The slight reduction in total chlorophyll content in some urban species, while indicative of stress, is effectively counteracted by the enhanced photoprotective capacity, This balance allows these plants to maintain photosynthetic efficiency and overall vitality even under challenging conditions, The inherent hardiness of species like Sidr, which showed relatively stable chlorophyll levels alongside increased carotenoids, further highlights its exceptional suitability for urban greening initiatives in arid regions [15]. Similarly, the adaptive responses of Date Palms, a species of immense cultural and economic importance in Iraq, confirm their potential to contribute significantly to urban biodiversity and ecosystem services [16].

In essence, the study confirms that the selected plant species are not merely surviving but actively adapting to the urban milieu of Najaf. Their ability to physiologically adjust their pigment systems represents a key adaptive strategy that enables them to withstand the pressures of urbanization, including air pollution, altered light regimes, and potentially elevated temperatures. These findings are invaluable for informing sustainable urban development strategies, particularly in rapidly urbanizing arid regions facing similar environmental challenges.

5. Future Research Directions

While this study provides a foundational understanding of physiological adaptations in urban plants of Najaf, several avenues for future research emerge:

1- Long-term Monitoring: Future studies should involve long-term monitoring of plant physiological responses across different seasons and over several years to capture seasonal variations and cumulative effects of urban stressors, This would provide a more dynamic understanding of adaptation processes [31].

2- Broader Physiological Parameters: Expanding the scope of physiological measurements to include parameters such as stomatal conductance, transpiration rates, water use efficiency, and antioxidant enzyme activities (e.g., superoxide dismutase, catalase, peroxidase) would offer a more holistic view of plant stress responses and adaptive mechanisms [32, 33].

3- Genetic and Molecular Basis of Adaptation: Investigating the genetic and molecular underpinnings of the observed physiological adaptations would provide deeper insights into the mechanisms of urban resilience, This could involve gene expression analysis related to stress response pathways and pigment biosynthesis [34].

4- Impact of Specific Pollutants: More targeted research on the effects of specific urban pollutants (e.g., heavy metals, particulate matter, specific gaseous pollutants) on plant physiology and growth in Najaf would be beneficial, This could involve controlled experimental setups or detailed spatial analysis of pollutant distribution and plant responses [6, 7].

5- Ecosystem Services Quantification: Quantifying the ecosystem services provided by these adapted urban plants, such as air purification capacity, carbon sequestration, and temperature regulation, would highlight their ecological and economic value to the city of Najaf [8, 9].

6- Socio-Ecological Perspectives: Integrating socio-ecological approaches to understand public perception of urban green spaces, community engagement in greening initiatives, and the cultural significance of specific plant species in Najaf would provide a more comprehensive framework for sustainable urban planning [35].

7- Comparative Studies with Other Arid Urban Environments: Comparative studies with other arid urban environments globally could identify common adaptive strategies and unique regional challenges, contributing to a broader understanding of urban plant ecology in drylands [36].

6. Recommendations for Urban Planning and Green Infrastructure in Najaf

Based on the findings of this study and the broader understanding of urban plant ecology, the following recommendations are proposed for urban planning and the development of green infrastructure in Najaf Governorate:

1- Prioritize Native and Well-Adapted Species: Emphasize the use of native and locally adapted plant species, such as Sidr and Date Palm, in urban greening projects, These species have demonstrated superior physiological resilience to the prevailing urban stressors in Najaf, ensuring higher survival rates and reduced maintenance requirements [10].

2- Strategic Placement of Vegetation: Implement strategic planting designs to maximize the benefits of urban vegetation, For instance, dense planting along major roads can help mitigate air pollution, while strategically placed trees can reduce the urban heat island effect by providing shade and evapotranspirational cooling [24].

3- Develop Green Corridors and Networks: Create interconnected green corridors and networks throughout the city to enhance biodiversity, facilitate ecological connectivity, and provide continuous pathways for air circulation and pollutant dispersion, This can also improve the aesthetic appeal and recreational opportunities within the city [25].

4- Integrate Green Infrastructure with Urban Development: Incorporate green infrastructure elements (e.g., green roofs, vertical gardens, permeable pavements) into new urban developments and existing infrastructure, These elements can help manage stormwater, reduce energy consumption, and enhance urban biodiversity [26].

5- Implement Sustainable Water Management Practices: Given Najaf's arid climate, sustainable water management practices are crucial for urban greening, This includes using drought-tolerant plant species, implementing efficient irrigation systems (e.g., drip irrigation), and exploring the use of treated wastewater for irrigation where appropriate [26].

6- Public Awareness and Community Engagement: Launch public awareness campaigns to educate residents about the importance of urban green spaces and the benefits of specific plant species, Encourage community participation in planting and maintenance activities to foster a sense of ownership and promote environmental stewardship [7].

7- Policy and Regulatory Frameworks: Develop and enforce robust policy and regulatory frameworks that support urban greening initiatives, protect existing green spaces, and promote the use of environmentally friendly materials and practices in urban development. This includes regulations on light pollution to minimize its impact on both human and ecological health [27].

8- Research and Development: Continue to invest in local research and development to identify additional resilient plant species, optimize planting techniques for urban environments, and monitor the long-term effectiveness of green infrastructure projects in Najaf, Collaboration between academic institutions, local government, and community organizations is essential for this [28].

By adopting these recommendations, Najaf Governorate can move towards a more sustainable and resilient urban future, where green spaces are not just ornamental but integral components of a healthy and thriving urban ecosystem, contributing significantly to the well-being of its residents and the preservation of its natural heritage, This holistic approach will ensure that urban development proceeds in harmony with the environment, creating a livable and sustainable city for current and future generations.

7. References

[1] A. A. Shumakova, V. A. Shipelin, N. V Trusov, and I. V Gmoshinski, “Content of essential and toxic trace elements in organs of obese Wistar and Zucker lepr rats receiving quercetin,” *J. Trace Elem. Med. Biol.*, vol. 64, p. 126687, Mar. 2021, doi: 10.1016/j.jtemb.2020.126687.

[2] pp. 1399-1419. https://doi. org/10. 18280/ijsdp. 20040. Althabhawi, G.J., Al-Khafaji, A.S. (2025). The role of accessibility to achieving sustainable revitalization of historic city centers: A study of the historic center of Al-Kifl City, Iraq. International Journal of Sustainable Development and Planning, Vol, “The Role of Accessibility to Achieving Sustainable Revitalization of Historic City Centers: A Study of the Historic Center of Al-Kifl City, Iraq,” *Int. J. Sustain. Dev. Planning, Vol. 20, No. 4, pp. 1399-1419.*, p. Vol. 20, No. 4, pp. 1399-1419., doi: https://doi.org/10.18280/ijsdp.200405.

[3] S. Farhan, U. Merie, and D. Alobaydi, “Challenges and opportunities of the urban structures of holy cities: the case of old Najaf, Iraq,” *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1129, p. 12034, 2023, doi: 10.1088/1755-1315/1129/1/012034.

[4] H. Admawi, “EVALUATION OF LIGHT POLLUTION IN THE STREETS AND THE ROADS OF AL-NAJAF CITY, IRAQ,” *Kufa J. Eng.*, vol. 11, pp. 62–77, 2020, doi: 10.30572/2018/KJE/110305.

[5] B. Almayahi, F. Alduhaidahawi, and K. Alasedi, “Hydrocarbon and trace elements concentrations in Najaf city, Iraq,” vol. 7, pp. 2127–2135, 2016.

[6] B. Almayahi, H. E, F. Alduhaidahawi, and A. H, “Heavy Metals Concentration in Different Soil Samples in Najaf City, Iraq,” *Int. J. Eng. Trends Technol.*, vol. 16, pp. 69–

71, 2014, doi: 10.14445/22315381/IJETT-V16P215.

[7] S. Kemeç and S. Abdalkarim, "Accessibility Analysis of Urban Green Space: The Case of Erbil City," *Iconarp Int. J. Archit. Plan.*, vol. 11, 2023, doi: 10.15320/ICONARP.2023.231.

[8] A. Najm and R. Khafaji, "Evaluation of Green Spaces in Hilla City According to Green Network Concept," *E3S Web Conf.*, vol. 427, p. 4012, 2023, doi: 10.1051/e3sconf/202342704012.

[9] A. M. Hussein, D. Neama Jabbar, and A. R. Ali, "Spatial distribution and evaluation of heavy metals in surface sediments of the Al-Najaf sea depression reservoir, Iraq," *Alexandria Eng. J.*, vol. 59, no. 6, pp. 5197–5206, Dec. 2020, doi: 10.1016/j.aej.2020.09.049.

[10] N. I. Al-Garaawi and B. A. Hamid, "A Survey Study of Wild Plants in AL Al Najaf Desert," *Int. J. Aquat. Sci.*, vol. 14, no. 1, pp. 42–67, 2023, [Online]. Available: https://www.journal-aquaticscience.com/article_165213.html

[11] H. al Rammahi and M. Mohammed, "THE CURRENT STATUS, ECOLOGICAL, BIOMETRICAL ASSESSMENT AND THREATS ON ACACIA GERRARDII NEGEVENSIS ZOHARY (FABACEAE) IN AL-NAJAF DESERT, IRAQ," vol. 20, pp. 4467–4476, 2020.

[12] H. Lichtenthaler, "Chlorophylls and carotenoids: Pigments of photosynthetic biomembranes," *Methods Enzymol.*, vol. 148C, pp. 350–382, 1987, doi: 10.1016/0076-6879(87)48036-1.

[13] D. I. Arnon, "Copper Enzymes in Isolated Chloroplasts. Polyphenoloxidase in Beta Vulgaris," *Plant Physiol.*, vol. 24, no. 1, pp. 1–15, 1949, doi: 10.1104/pp.24.1.1.

[14] S. M. A., "The spectral determination of chlorophylls a, b and total carotenoids using various solvents for tree species growing near sugar mill," *Asian J. Exp. Chem.*, 2011.

[15] A. Hafeez, R. Rasheed, M. A. Ashraf, and I. Hussain, "Plants and their Interaction to Environmental Pollution Effect of heavy metals on growth, physiological and biochemical responses of plants," no. December, 2022, doi: 10.1016/B978-0-323-99978-6.00006-6.

[16] A. Singh, R. Eram, M. Agrawal, and S. Agrawal, "Air Pollution: Sources and its Effects on Humans and Plants," *Int. J. PLANT Environ.*, vol. 8, pp. 10–24, 2022, doi: 10.18811/ijpen.v8i01.02.

[17] A. Hafeez, R. Rasheed, M. Ashraf, F. Qureshi, I. Hussain, and M. Iqbal, "Plants and their Interaction to Environmental Pollution Effect of heavy metals on growth, physiological and biochemical responses of plants," 2022. doi: 10.1016/B978-0-323-99978-6.00006-6.

[18] A. Rizki, S. Setiawati, and S. Rushayati, "The Impact of Urban Green Space on The Urban Heat Island Phenomenon – A Study Case in East Jakarta, Indonesia," *Geoplanning J. Geomatics Plan.*, vol. 11, pp. 31–42, 2024, doi: 10.14710/geoplanning.11.1.31-42.

[19] B. Demmig-Adams, "Demmig-Adams, B. Carotenoids and photoprotection in plants: a role for the xanthophyll zeaxanthin. Biochim. Biophys. Acta 1020, 1-24," *Biochim. Biophys. Acta-bioenergetics - BBA-BIOENERGETICS*, vol. 1020, pp. 1–24, 1990, doi: 10.1016/0005-2728(90)90088-L.

[20] V. Uarrota, D. Stefen, L. Leolato, D. Medeiros Gindri, and D. Nerling, "Revisiting Carotenoids and Their Role in Plant Stress Responses: From Biosynthesis to Plant Signaling Mechanisms During Stress," in *Antioxidants and Antioxidant Enzymes in Higher Plants*, 2018, pp. 207–232. doi: 10.1007/978-3-319-75088-0_10.

[21] W. Stahl and H. Sies, "Antioxidant activity of carotenoids," *Mol. Aspects Med.*, vol. 24, pp. 345–351, 2004, doi: 10.1016/S0098-2997(03)00030-X.

[22] V. Sissakian, H. Jassim, N. Adamo, N. Al-Ansari, and N. Al-Ansary, "Consequences of the Climate Change in Iraq Consequences of the Climate Change in Iraq," *Glob. J. Human-Social Sci.*, vol. 22, pp. 13–26, 2022, doi: 10.34257/GJHSSBVOL22IS2PG13.

[23] S. Lata and Siddharth, "Sustainable and eco-friendly approach for controlling industrial wastewater quality imparting succour in water-energy nexus system," *Energy Nexus*, vol. 3, p. 100020, Dec. 2021, doi: 10.1016/j.nexus.2021.100020.

[24] J. A. Knowles, "National solid waste management plan for Iraq," *Waste Manag. Res. J. a Sustain. Circ. Econ.*, vol. 27, no. 4, pp. 322–327, Jun. 2009, doi: 10.1177/0734242X09104129.

[25] R. Pranckutė, "Web of Science (WoS) and Scopus: The Titans of Bibliographic Information in Today's Academic World," *Publications*, vol. 9, no. 1, p. 12, Mar. 2021, doi: 10.3390/publications9010012.

[26] J. Mentens, D. Raes, and M. Hermy, "Green Roofs as a Tool for Solving the Rainwater Runoff Problem in the Urbanized 21st Century?," *Landsc. Urban Plan.*, vol. 77, pp. 217–226, 2006, doi: 10.1016/j.landurbplan.2005.02.010.

[27] D. L. Sparks, "Elucidating the fundamental chemistry of soils: past and recent achievements and future frontiers," *Geoderma*, vol. 100, no. 3–4, pp. 303–319, May 2001, doi: 10.1016/S0016-7061(01)00026-X.

[28] M. R. Magee, L. Siebenaler, K. Maguire, K. Ackley, and T. Killestein, "Quantitative modelling of type Ia supernovae spectral time series: constraining the explosion physics," *Mon. Not. R. Astron. Soc.*, vol. 531, no. 3, pp. 3042–3068, Jun. 2024, doi: 10.1093/mnras/stae1233.