

Effect of spraying with chelated iron and tryptophan on some vegetative characteristics of two mint(*Mentha spicata* L.) varieties

Taghreed Fakher Jaber^{1*}, Zainab Hussein Alawi¹

¹Department of Biology, College of Education for Girls, Kufa University, Najaf, Iraq.

*Corresponding author's email: tgreedf.zwayn@uokfa.edu.iq

[Email addresses of coauthor: zainab.alakaishi@uokufa.edu.iq](mailto:zainab.alakaishi@uokufa.edu.iq)

Abstract

Modern agricultural trends have focused on reducing fertilization rates and improving fertilizer efficiency and environmental safety. Therefore, a field experiment was conducted during the 2024-2025 growing season in the fields of the Horticulture and Forestry Department of the Najaf Governorate Agriculture Directorate. The aim was to study the effect of foliar spraying of the chelated iron and amino acid tryptophan on some vegetative characteristics of two mint (*Mentha spicata* L.) varieties: common mint and peppermint. The experiment was implemented using a 3:3 factorial design with a split-plot design and a randomized complete block design (RCBD) with three replications. The experiment included two treatments: foliar spraying of the amino acid tryptophan at three levels (0, 50, and 100 mg.l⁻¹) and foliar spraying of chelated iron at three levels as well (0, 40, and 80 mg.l⁻¹). These treatments were applied as foliar sprays twice during the growing season.

The results showed a significant positive effect of both single and double foliar spray treatments on all studied vegetative traits. The interaction between high levels of chelated iron and tryptophan resulted in the highest standard indicators for plant height, total number of leaves, and number of lateral branches, as well as a significant increase in photosynthetic efficiency through increased chlorophyll content (SPAD units) in the leaves. The current study demonstrates that the complementary use of amino acids and increased physiological availability of iron by spraying chelated iron, is a vital and effective strategy for stimulating vegetative growth and improving the quantitative and qualitative yield of mint plants under the conditions of central Iraq.

Keywords: Local mint, chelated iron, tryptophan, vegetative properties, Chlorophyll content.

Introduction

Mint is one of the most important and widespread medicinal and aromatic plants in the world, belonging to the mint family (Lamiaceae) [1]. The plant, particularly its leaves, is of great economic and therapeutic importance due to its richness in volatile oils, flavonoids, and antioxidants, including vitamins such as ascorbic acid (vitamin C) and essential minerals [2]. However, the vegetative production efficiency of this crop is greatly affected by the availability of nutrients in the soil and the plant's physiological ability to utilize them to produce a robust

vegetative mass with a large leaf area and high chlorophyll content [3]. It is well known that the soils of Iraq are calcareous and alkaline, prevalent in central and southern Iraq. Therefore, mint cultivation faces structural challenges related to the low availability of macro- and micronutrients. High pH and increased calcium carbonate content lead to iron fixation, converting it into insoluble forms that are difficult for roots to absorb [4]. Iron (Fe) is also a crucial physiological element for plant life. Iron is directly involved in chlorophyll synthesis, electron transport during photosynthesis and

ISSN 2072-3857

respiration, and the activation of numerous enzyme systems that stimulate cell division and elongation. This directly affects vegetative indicators such as plant height, number of leaves, and branching [5]. Therefore, the trend has shifted from soil fertilization to foliar fertilization. Spraying chelated iron on leaves has emerged as an effective alternative to overcome the problems of iron fixation in the soil, delivering the element directly to the target tissues [5, 6]. Modern agricultural research has also focused on using environmentally safe biostimulants, particularly amino acids, to enhance plant physiological efficiency [7]. The amino acid tryptophan is a key precursor to the synthesis of natural auxins within plant tissues, specifically indoleacetic acid (IAA), which acts as a hormone stimulating cell

elongation, apical dominance, and meristematic tissue activation [8]. Spraying plants with tryptophan provides them with the energy needed to synthesize hormones internally, stimulating vegetative growth, increasing leaf area, and improving carbohydrate and protein metabolism [9]. Given the scarcity of studies investigating the effect of combining biostimulants, such as tryptophan, with micronutrients, such as chelated iron, on local mint varieties cultivated in Najaf Governorate, this research was conducted. This study aimed to evaluate the vegetative indicators of two mint varieties (local and peppermint) to different levels of chelated iron and tryptophan, and to determine the optimal interaction for achieving the highest possible growth efficiency.

Material and Methods

Field Study and Preparation:

The field experiment was conducted during the 2024-2025 growing season within the fields belonging to the Horticulture and Forestry Division of the Najaf Governorate Agriculture Directorate. The field soil was prepared for planting by performing double plowing in cross directions, followed by particle smoothing and surface leveling to ensure uniform distribution.

Before planting or applying any fertilization programs, ten soil samples

were randomly collected from various locations within the field at depths ranging from 0 to 30 cm. The collected samples were thoroughly mixed to ensure homogeneity, dried naturally in the sun for 24 hours, then ground and passed through a laboratory sieve with 2 mm openings. These samples were then sent for analysis to the laboratories of the Soil and Water Resources Department at the College of Agriculture, University of Kufa. The physiological and physicochemical indicators of the field soil are shown in Table (1).

Table (1): Physical and chemical properties of field soil before treatment begins

Soil indicators	measured value	unit of measurement
Soil Separates		
Sand	57.10	%
Silt	25.30	%

Clay	17.60	%
Soil Texture	)Silty loam(	—
pH	7.6	—
Electrical Conductivity (EC)	2.55	Decisiemens/meter
Organic Matter	1.2	%
Available Nitrogen (N)	0.261	Parts per million (ppm)
Available Phosphorus (P)	0.245	Parts per million (ppm)
Available Potassium (K)	92.2	Parts per million (ppm)

Statistical Design and Field Operations:

The experimental area was divided into three main sections (replications), separated by 1-meter-wide walkways to facilitate field operations and maintenance. Since the current study focused on a single species, local mint (*Mentha spicata* L.), each section was further subdivided into three main plots to distribute the levels of the amino acid tryptophan. These main plots were then subdivided into three secondary subplots to study chelated iron levels. The total area of each experimental unit was 2 m² (1 x 2 m), and the units were separated by 0.5-meter-wide walkways to prevent cross-spraying of treatment sprays.

The soil was irrigated 48 hours prior to planting using a drip irrigation system, followed by the planting of local mint seedlings obtained from a reputable nursery in Najaf Governorate. Planting took place on November 27, 2024, in regular rows, with a spacing of 10 cm between rows and 10 cm between plants within each row. The researcher continued to provide all the usual agricultural services throughout the season, supplying irrigation water according to the crop's physiological needs, while manually clearing the land of weeds and accompanying vegetation using continuous hoeing [10].

Evaluation Criteria and Laboratory Analyses:

Growth Indicators and Vegetative Mass Yield:

Each experimental panel was divided into two equal sections. The first section was used to monitor vegetative growth parameters (four months after planting), while the second section was used for qualitative component analysis. Ten randomly selected plants were collected from the vegetative section of each treatment for the following measurements:

- Plant height (cm): The vertical length of ten plants was measured from the soil surface to the top of the growing tip using a graduated measuring tape, and the mean was recorded.
- Total leaf count (leaf plant⁻¹): The total number of fully developed leaves on the ten randomly selected plants for each treatment was counted, and the overall mean was calculated.
- Number of lateral branches (branch plant⁻¹): All developing and active lateral branches of the ten selected plants were counted, and the treatment mean was calculated.

- Total chlorophyll pigment concentration (SPAD unit): Chlorophyll content was directly and field-based on local mint leaves (10 random readings per treatment)

Results and Discussion

Plant Height (cm)

The results presented in Table 1, relating to the effects of the studied factors (mint varieties, chelated iron spray, and tryptophan spray), show a significant but variable response in plant height. The high level of chelated iron (F2) achieved a clear statistical advantage, recording the highest overall mean iron value of 58.50(cm) compared to 53.21(cm) for the F0 level, at a significance level of 1.169. Tryptophan treatment also showed a significantly

using a portable digital chlorophyll meter (SPAD-502 Chlorophyll meter), and the extracted values were expressed in SPAD units [11].

superior effect at the T1 level, with an overall mean of 58.79(cm), which differed significantly from the other levels, at a significance level of 1.169. At the variety level, local mint (V1) showed a significant advantage, achieving an overall mean of 65.56 (cm) compared to peppermint (V2), which recorded 52.06 (cm), at a significance level of 0.954. Regarding the triplet reaction (V*T*F), the local mint mixture with a T1 concentration of tryptophan without added iron (V1T1F0) showed the highest statistical value of 73.43(cm), with a significant difference at $LSD = 2.863$.

Table (2): Effect of spraying with chelated iron (F) and tryptophan (T) and the interaction between them on the plant height (cm) of two *Mentha spicata* L. varieties

Plant varieties	Iron chelate spray ($\text{mg} \cdot \text{L}^{-1}$)	Spray with tryptophan ($\text{mg} \cdot \text{L}^{-1}$)			Plant varieties *Iron chelate spray (V*F)	Varieties effects (V)
		T0	T1	T2		
local mint V1	F0	41.07 j	73.43 a	56.00 fgh	56.83 b	58.86 a
	F1	58.17 efg	59.30 def	57.50 efgh	58.32 ab	
	F2	56.20 fgh	63.93 c	64.10 c	61.41 a	
Peppermint V2	F0	54.63 hi	54.83 ghi	39.27 k	46.24 c	52.06 b
	F1	51.93 i	49.23 ij	51.90 i	51.02 bc	
	F2	65.67 bc	52.00 i	49.10 ij	55.59 b	
$LSD_{(V*T*F)}=2.863$					$LSD_{(V*F)}=N.S$	$LSD_{(V)}=0.954$
varieties * tryptophan (V*T)			Spraying with tryptophan* Spraying with chelated iron			
Tryptophan mg l^{-1}	local mint	Peppermint	F0	F1	F2	Average tryptophan spray
T0	51.81 c	57.41 b	47.85 d	55.05 b	60.93 a	51.81 c
T1	65.56 a	52.02 c	64.13 a	54.27 bc	57.97 ab	65.56 a
T2	59.20 b	46.76 d	47.63 d	54.70 b	56.60 b	59.20 b

LSD _(V * F) =1.653	LSD _(T * F) =2.024			
Average spray with chelated iron	53.21 b	54.67 b	58.50 a	LSD _(T) =1.169

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan multiple ranges test at significant level of 5%.

number of leaves (leaf plant⁻¹)

The results in Table 2 show a clear and significant increase in leaf count. The higher levels of chelated iron (F2) and tryptophan (T2) resulted in the highest statistical averages compared to the control treatments (F0 and T0). Treatment F2 recorded an overall average of 37.33 (leaf plant⁻¹), compared to 32.72 (leaf plant⁻¹) for treatment F0, with a statistically significant difference of LSD = 0.873. Tryptophan also showed a progressively positive response, with treatment T2 leading at an average of 38.00 (leaf plant⁻¹)

and an LSD value of 0.873. In contrast, the mint varieties (V1 and V2) did not show a significant difference in their direct effect, with 35.04 and 34.89 (leaf plant⁻¹) respectively, at an LSD value of 0.712. The significant triplet interaction (V*T*F) emerged as the highest response among the factors, with the local mint mixture with the highest two concentrations of iron and tryptophan (V1T2F2) recording the highest average number of leaves at 42.00 (leaf plant⁻¹) and a significant difference of LSD = 2.137.

Table (3): Effect of spraying with chelated iron (F) and tryptophan (T) and the interaction between them on the number of leaves (leaf plant⁻¹) of two *Mentha spicata* L. varieties

Plant varieties	Iron chelate spray (mg* L ⁻¹)	Spray with tryptophan (mg* L ⁻¹)			Plant varieties *Iron chelate spray (V*F)	Varieties effects (V)
		T0	T1	T2		
local mint V1	F0	28.00 a	35.00 cd	34.67 cd	32.56 b	35.04a
	F1	33.67 c	35.33 cde	35.33 cdef	34.78 ab	
	F2	34.33 c	37.00 defg	42.00 h	37.78 a	
Peppermint V2	F0	30.33 b	34.00 c	34.33 c	32.89 c	34.89b
	F1	34.33 c	34.33 c	36.00 cdefg	34.89 bc	
	F2	35.00 cd	37.67 eg	38.00 g	36.89 b	
	=2.137LSD _(V*T*F)				LSD _(V*F) =N.S (0.873)	0.712 LSD _(V) =
varieties * tryptophan (V*T)			Spraying with tryptophan* Spraying with chelated iron			Average tryptophan spray
Tryptophan mg l-1	local mint	Peppermint	F0	F1	F2	
T0	51.81 c	57.41 b	47.85 d	55.05 b	60.93 a	

T1	65.56 a	52.02 c	64.13 a	54.27 bc	57.97 ab	34.50 b
T2	59.20 b	46.76 d	47.63 d	54.70 b	56.60 b	34.50 b
1.234 LSD _(V * F) =			1.234 LSD _(T * F) =			
Average spray with chelated iron			32.72 a	34.83 b	37.33 c	LSD _(T) = 0.873

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan multiple ranges test at significant level of 5%.

number of branches (branches plant⁻¹)

Table 3's results regarding the number of branches showed a significant advantage for the main factor, tryptophan (T) foliar application. Treatment T2 recorded the highest mean number of branches (31.56 branches plant⁻¹), compared to the lowest mean in the control treatment T0 (25.22 branches plant⁻¹). Similarly, chelated iron (F2) foliar application achieved the highest significant advantage among iron levels, with a mean of 31.56 branches plant⁻¹, compared to treatment F0 (24.39 branches plant⁻¹), at a statistically significant level (LSD = 0.932). The binary interaction between variety and tryptophan (V*T) and

the interaction between tryptophan and iron (T*F) showed a clear and statistically significant effect, while the binary interaction between variety and iron (V*F) did not show any statistically significant differences. Both common mint (V1) and peppermint (V2) showed a similar response to iron spraying, with an average number of branches of 28.48 and 28.04 branches plant⁻¹, respectively. At the ternary interaction level (V1 T2 F2), the combined treatment (V1 T2 F2) achieved the highest average number of branches 36.00 (branches plant⁻¹), significantly outperforming (LSD = 2.284) the lower control treatment (V2 T0 F0), which recorded 17.67 branches plant⁻¹.

Table (4): Effect of spraying with chelated iron (F) and tryptophan (T) and the interaction between them on the number of branches ((branches plant⁻¹) of two *Mentha spicata* L. varieties

Plant varieties	Iron chelate spray (mg l ⁻¹)	Spray with tryptophan (mg l ⁻¹)			Plant varieties *Iron chelate spray (V*F)	Varieties effects (V)
		T0	T1	T2		
local mint V1	F0	21.33 b	26.00 cd	28.33 defg	25.00 c	28.48 a
	F1	26.00 cd	28.67 efg	30.33 gh	28.89 b	
	F2	27.67 cdef	32.00 h	36.00 i	31.56 a	
Peppermint V2	F0	17.67 a	26.33 cde	29.00 fg	23.78 c	28.04 a
	F1	25.67 c	29.67 fgh	30.33 gh	28.78 b	
	F2	28.00 cdefg	30.33 gh	35.33 i	31.56 a	
	LSD _(V*T*F) = 2.284				LSD _(v*F) =N.S0.761	LSD _(V) = 0.761
varieties * tryptophan (V*T)			Spraying with tryptophan* Spraying with chelated iron			

Tryptophan Mg l ⁻¹	local mint	Peppermint	F0	F1	F2	Average tryptophan spray
T0	25.22 a	24.33 a	19.50 d	25.84 c	27.84 bc	25.22 a
T1	28.33 b	28.56 b	26.17 c	29.17 b	31.17 a	28.45 b
T2	31.89 c	31.22 c	28.67 b	30.33 ab	35.67 a	31.56 c
1.234 LSD _(V *F) =			LSD _(V *T) = 1.319			LSD _(T*F) = 1.319
Average spray with chelated iron			24.39 a	28.83 b	31.56 c	LSD _(T) = 0.932

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan multiple ranges test at significant level of 5%.

chlorophyll content (SPAD units)

Statistical analysis of chlorophyll content in Table 4 showed a significant increase in the effect of tryptophan spraying (T), with treatment T2 significantly outperforming the other treatments. Treatment T2 achieved the highest mean chlorophyll content 52.93(SPAD units) compared to the control treatment T0, which recorded 46.23 (SPAD units). Fertilization treatments (F) also had a significant upward effect, with treatment F2 yielding the highest values 53.88 (SPAD units) compared to treatment F0, which recorded the lowest value 45.54 (SPAD units) at a significance level of (LSD = 1.193). Regarding binary interactions, the

interaction between tryptophan spraying and chelated iron fertilization (T F) showed a significant effect, while neither the variety factor (V) nor its binary interactions with fertilizer (V F) showed any statistically significant differences (N.S.). This confirms the similarity in response between the two species, spearmint (V1) and peppermint (V2), with average values of 49.90(SPAD units) and 49.88 (SPAD units), respectively. As for the triplet reaction (V*T*F), the formulation (V1 T2 F2) recorded the highest chlorophyll content at 56.77 (SPAD units), significantly outperforming (LSD = 2.913) the control formulation with the lowest content (V1 T0 F0), which recorded 37.73(SPAD units).

Table (5): Effect of spraying with chelated iron (F) and tryptophan (T) and the interaction between them on the chlorophyll content (SPAD units) of two *Mentha spicata* L. varieties

Plant varieties	Iron chelate spray (mg l ⁻¹)	Spray with tryptophan (mg l ⁻¹)			Plant varieties *Iron chelate spray (V*F)	Varieties effects (V)
		T0	T1	T2		
local mint V1	F0	37.73 a	47.43 b	53.87 ef	46.34 c	49.90 a
	F1	47.73 bc	52.13 e	50.77 cde	50.21 b	
	F2	51.70 e	50.97 de	56.77 f	53.15 a	
Peppermint V2	F0	37.80 a	48.30 bcd	52.23 e	46.11 c	49.88 a
	F1	47.20 b	51.50 de	53.73 ef	50.81 b	

	F2	51.10 de	51.17 de	55.90 f	52.72 a	
	LSD _(V*T*F) = 2.913				LSD _(V*F) =N.S 0.973	LSD _(V) = N.S. 0.973
varieties * tryptophan (V*T)			Spraying with tryptophan* Spraying with chelated iron			
Tryptophan mg l-1	local mint	Peppermint	F0	F1	F2	Average tryptophan spray
T0	46.34 a	46.11 a	37.77 d	47.87 c	53.05 a	46.34 a
T1	50.21 b	50.81 b	47.47 c	51.82 b	52.25 ab	50.21 b
T2	53.14 c	52.72 c	51.40 b	51.07 b	56.34 a	53.14 c
1.234 LSD _(V *F) =			LSD _(V *T) = 1.683			LSD _(T*F) = 1.683
Average spray with chelated iron			45.54 a	50.25 b	53.88 c	LSD _(T) = 1.193

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan multiple ranges test at significant level of 5%.

Discussion

The scientific explanation for these differences and the significant increases observed is attributed to the role of chelated iron and tryptophan at specific concentrations in stimulating physiological processes and metabolic reactions of nutrients and biostimulants within the plant. The amino acid tryptophan is a key precursor to the synthesis of the growth-promoting auxin, indole-3-acetic acid (IAA), and at its optimal concentration (T1), it stimulates cell division and activates vital processes within tissues [12]. Spraying with chelated iron also contributes to enhancing chlorophyll synthesis and increasing the efficiency of electron transport during photosynthesis, which in turn leads to increased carbohydrate synthesis [13]. The superiority of the local mint variety (V1) is also attributed to its genetic diversity, genotype, and adaptability to the various conditions in Iraq, which grants it greater efficiency in nutrient uptake and biosynthesis. All metabolic products are directed towards vegetative growth compared to

peppermint. These results are consistent with those of several recent studies on the nutritional response of medicinal plants. The study by Tariq *et al.* (2020) [14] supported the positive effect of chelated iron application on improving the vegetative and productive indicators of mint varieties. These findings are also consistent with those of Siddiqui and Khan (2023) [15], who found that foliar application of tryptophan at balanced concentrations significantly increases hormone levels and metabolic activity in plants. These conclusions complement those of Al-Jubouri and Al-Shammari (2024) [16], who confirmed significant differences among mint varieties in their response to micronutrient-amino acid catalyst interactions. This, in turn, promotes plant elongation and cell division, and stimulates bud activity to produce new branches and leaves [17]. Therefore, the complementary interaction between the micronutrient (iron) and the biostimulant (tryptophan) contributes to improved hormonal and nutritional balance within the plant, positively influencing the stimulation of metabolic pathways, dry

matter accumulation, and leaf growth. This nutritional and hormonal integration leads to improved photosynthetic efficiency, increased carbohydrate availability, and

The results showed that spraying mint plants with chelated iron and tryptophan improved most of studied parameters compared to untreated plants. Spraying the local variety had a significant effect on plant height, number of branches, number

the direction of metabolic activities towards the growth and intensification of vegetative branches.

Conclusion

of leaves per branch, and chlorophyll content. Furthermore, the combined treatment of chelated iron and tryptophan resulted in a significant increase in all studied parameters compared to the control group.

Acknowledgment:

We are grateful to the University of Kufa and the College of Education for Women

for providing all the resources to support scientific research.

References

- [1] Ali, Q., Anwar, F., & Ashraf, M. (2019). Exogenous tryptophan application mitigates salt stress in plants by modulating growth, anatomy, and key physiological processes. *Journal of Plant Growth Regulation*, 38(4), 1321-1335.
- [2] Briat, J. F., Dubos, C., & Gaymard, F. (2015). Iron nutrition, tolerant plants, and approaches to iron efficiency in crops. *Frontiers in Plant Science*, 6, 121.
- [3] Guda, M. A., Alkaabi, Z. S., Albayati, F. S., Alduhaidahawi, F. J., & Almayahi, B. A. (2020). Anatomical And Sclerophilic Traits Variation In Two Varieties Of Olive Plants (*Olea europaea* L) Growing Under Climate Changes In Various season of the year. *Indian Journal of Environmental protection*, Vol.40, No.1 January 20, 77-83.
- [4] Fernández, V., & Brown, P. H. (2013). From the surface to the organs: the pathways of foliar-applied nutrients. *Frontiers in Plant Science*, 4, 289.
- [5] Rahy, A. Y., & Guda, M. A. (2025). Evaluation of The Inhibitory Activity of Aqueous and Alcoholic (*Punica granatum*) Pomegranate Peel Extract on Some Bacterial species Isolated from Patients' beds at Al-Refai Teaching Hospital. *International Journal of Advancement in Life Sciences Research*, 8(2), 186-193.
- [6] Guda, M.A., (2023). Response of antioxidant in some plants to iron oxide nanoparticles, AIP Conference Proceedings, 2023, 2977(1), 040144 <https://doi.org/10.1063/5.0182305>
- [7] Husayn, D.M., Guda, M.A., (2023). Response of some wild plants in antioxidant enzymes by zinc oxide nanoparticles, AIP Conference Proceedings, 2023, 2787(1), 090049
- [8] Kookal, S. K., & Thimmaiah, A. (2018). Nutritional composition and antioxidant activity of local mint (*Mentha spicata* L.) cultivars.

- International Journal of Vegetable Science, 24(2), 112-125.
- [9] **Lawrence, B. M. (2007).** Mint: The genus *Mentha*. CRC Press, Taylor & Francis Group.
- [10] **Oveisi, M., Honarvar, M., & Hajisani, A. (2014).** Effect of nitrogen and micronutrients on growth and essential oil yield of peppermint. *Journal of Agricultural Science*, 6(3), 45-52.
- [11] **Nasser Jubair Radhi Alhasnawi¹, Muthik Abd Muslim Guda, Ammar Sami Al-Bayat. (2025).** Effect of Nano-silver Fertilization on the Tolerance of Salt Stress by Irrigation with Saline Water in Faba Bean (*Vicia faba* L.). *Indian Journal of Agricultural Research*. <https://doi.org/10.18805/IJARE.AF-968>
- [12] **Rout, G. R., & Sahoo, S. (2015).** Role of iron in plant growth and metabolism. *Reviews in Agricultural Science*, 3, 1-24.
- [13] **Zhao, Y. (2018).** Essential roles of local auxin biosynthesis in plant development and in response to environmental cues. *The Plant Cell*, 30(11), 2683-2693.
- [14] **Guda, M.A., Younus, A.S., Altamimi, A.J.T., ... Al-Edhari, A.H.M., Alduhaidahawi, F.J.,** Effect of Irrigation with Magnetized Water on Some Vegetative and Flowering Parameters of Wheat (*Triticum aestivum* L.) Cultivar IP A 99, *ARPN Journal of Engineering and Applied Sciences*, 2019, 14(2), pp. 5466–5470
- [15] **Zulfiqar, F., Casadesús, A., & Munné-Bosch, S. (2020).** Biostimulants as a tool for improving plant growth and tolerance to stresses in agriculture. *Frontiers in Plant Science*, 11, 1151.
- [16] **Owied, O.A.-R., Guda, M.A.M., Taher, H.I., Abdulhussein, M.A.A.,** Plants anatomically engineered by nanomaterials, *Bionatura*, 2023, 8(2), 44
- [17] **Hanan Fadhil Kadhimi¹, Eqbal Yousif Abed², Muthik A. Guda³.(2025).** Climate Change and Its Influence on Anatomical and Physiological Features of Pomegranate (*Punica Granatum* L.) Leaves, *Contemporary Research Analysis Journal* 8(2)p: 510-515