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Effect of Foliar Application of Chelated Iron and Micro-Mix Nutrient Solution on the Growth and Yield of the Haimer Tomato Hybrid Under Unheated Plastic House Conditions

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ABSTRACT

The experiment was conducted in plastic houses, College of Agriculture, University of Anbar, during 2023-2024 fall season of 2023, to study the effect of some nutrients on the growth and yield of the Haimer tomato hybrid. The experiment included two factors: the first factor was spraying with iron at four concentrations (0, 2.5, 3, and 4.5 g L⁻¹), and the second factor was spraying with the nutrient solution Micro mix at four concentrations (0, 2.5, 3.5-, and 4.5-ml L⁻¹). The factorial experiment was carried out within a Randomized Complete Block Design (R.C.B.D) with factorial 16 treatments and three replicates. The means were compared with L.S.D. test at a 5% probability level the results were analyzed statistically using the Gen Stat statistical program. The results indicate the superiority of the treatment with the Micro-mix nutrient spray at a concentration of 4.5 ml L⁻¹ and the iron spray at a concentration of 4.5 ml L⁻¹, as well as their interaction, in the studied traits. These treatments produced the highest values in plant height (180.0 cm) and (171.5 cm), number of leaves (77.42) and (73.07), number of flower clusters (10.30) and (9.68), number of flowers per cluster (15.86) and (13.87), number of fruits per plant (22.75) and (23.08), fruit diameter (37.53 mm) and (42.61 mm), fruit length (23.58 mm) and (24.84 mm), and yield per plastic house 500 meter square (3.683 tons) , (3.511 tons), number flowers set, fruit weight , plant yield respectively, compared to the control treatment.

Keywords: *Solanum lycopersicum* L., Fertilizer, Nutrient.

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INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the Important vegetable crops belonging to the Solanaceae family. It has high nutritional values due to its fruit's content of nutrients such as potassium and several acids such as ascorbic acid (Vitamin C), citric acid, and malic acid, as well as vitamins like Vitamin E and some phenolic compounds. It also contains pigments such as carotene and lycopene [1]. Since tomatoes are among the richest vegetables in nutritional value, their consumption in large quantities gives them priority in providing nutrients and vitamins. They ranked third as a source of Vitamin C and A, and they ranked first as a source of many vitamins and minerals combined compared to other vegetable crops [2].

Tomato plants consume large amounts of nutrients, which necessitates the continuous provision of essential elements throughout their growth period. Foliar spraying is an effective method for better nutrient translocation within the plant and contributes to improving growth and increasing yield both in quantity and quality. This highlights the importance of foliar spraying during the growing season [3, 4]. Studies indicate the significant role of iron, a nutrient with slow mobility within the plant, especially in phloem tissues. Iron's ability to change valence states and balance redox potential, as well as its role in photoreductive respiration reactions, is well-documented [5]. The importance of iron stems from its role in chlorophyll synthesis in the plant and the activity of many enzymes which is facilitated to iron's ability to gain and lose electrons in redox processes within plant tissues, including respiratory enzymes. Iron is involved in the composition of cytochromes, which are crucial for photosynthesis, and it also plays a role in the formation of protein plant.

The diverse variation in growth vigor and yield is influenced by the environmental diversity of tomato hybrids and may also be attributed to genetic differences between hybrids that grow under the same environmental conditions. There are wide genetic differences among hybrids and cultivars depending on the nature of growth and production [6, 7, 8]. Since tomato genetic hybrids vary in their response to nutrition, selecting the appropriate genetic hybrids and determining the suitable foliar nutrient is important for achieving higher yields with better quality [9, 10].

This study aimed to investigate the effect of foliar application with iron and Micro- mix nutrient solution on the growth and yield of The tomato hybrid Heimer in unheated greenhouses under the environmental conditions of Anbar, Iraq.

Materials and Methods

The experiment was conducted in one of the greenhouses (500 m² area) belonging to the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Anbar, during 2023-2024 Fall. The seeds of the Haimar-F1 hybrid

(indeterminate growth) were used for planting. The seeds were sown on 15/10/2023 in the nursery, and after reaching the stage of four to five true leaves, they were transplanted to the greenhouse on 1/12/2023. The growth system was based on training each plant to a single stem.

The seedlings were planted at a distance of 0.40 meters from each other in an alternating pattern, with each experimental unit containing 40 plants. Service operations such as irrigation, weeding, pest control and the addition of chemical fertilizers were carried out according to fertilization recommendations [11]. Drip irrigation pipes were laid for the three replicates, with each replicate having two pipes. The drip irrigation openings were spaced at intervals of 40 cm between each opening, and the distance between each line of pipes was 0.3m. The replicates were completely covered with black plastic soil mulch, and the edges of the cover were buried in the soil to ensure a tight seal. The plastic house soil was irrigated for several days. The seedlings were grown in a greenhouse with sandy loam soil

The treatments were as follows: Chelated Iron was symbolized as Change to F (with four concentrations: 0, 2.5, 3.5, and 4.5 g L⁻¹ of water), and the Iron Nutrient Solution

(Micro-mix) was symbolized as C (with four concentrations: 0, 2.5, 3.5, and 4.5 ml L⁻¹ of water). The spraying process was carried out 45 days after transplanting the seedlings, at the beginning of the appearance of the first flower cluster. The spraying continued for a total of 5 sprays, with one spray every 10 days.

Table 1. Composition of Micro-mix solution and its element ratios

Element	%	Symbol
Boron	0.45	B
Zinc	0.40	Zn
Iron	0.30	Fe

Studied Traits:

Five plants were randomly selected from each experimental unit to determine growth and yield traits, which were included: Plant height, number of leaves, number of flower clusters, number of flowers per cluster, number of fruits per plant, fruit diameter, fruit height; yield (tons per greenhouse 500meter square), number of flowers set, fruit weight, and plant yield.

Statistical analysis

The data were analyzed using the statistical program GenStat, and the means were compared using the Least Significant Difference (LSD) test at a 5% probability level.

Results and Discussion

Plant height (cm)

The results shown in Table 2 indicate that the treatment C4.5 outperformed the other treatments, providing the highest plant height of 180.0 cm plant⁻¹, compared to C0, which gave the lowest results at 140.3 cm plant⁻¹. The same table shows that iron spraying in treatment F3.5 resulted in a plant height of 171.5 cm plant⁻¹, compared to F0, which gave the lowest results at 159.0 cm plant⁻¹. The results revealed a significant interaction between the two factors, iron spraying and the nutrient solution, the treatment C4.5 F3.5 recorded the highest value of 187.6 cm plant⁻¹, compared to C0F0, which gave the lowest results at 133.6 cm plant⁻¹.

Table 2: The effect of foliar application with Chelated iron and Micro- max nutrient solution on plant height (cm)

Nutrient solution C	Chelated iron levels F				Mean C
	F0	F2.5	F3.5	F4.5	
C0	133.6	137.6	147.6	142.3	140.3
C2.5	154.0	161.0	171.0	172.3	164.5
C3.5	174.3	175.3	180.0	174.6	176.0
C4.5	174.0	172.6	187.6	186.0	180.0
Mean F	159.0	161.6	171.5	168.8	
LSD0.05C= 3.31					F = 6.63×LSD- 0.05C

Leaves number (leaf plant⁻¹)

The results presented in Table 3 demonstrate that the C4.5 treatment achieved the highest number of leaves per plant, totaling 77.42 leaf, significantly outperforming the C0 treatment, which recorded the lowest number at 59.46 leaf. The results shows that iron spraying in treatment F3.5 resulted in 83.60 leaf, compared to F0, which gave the lowest number at 67.43 leaf. The results indicate a significant interaction between iron spraying and the nutrient solution, the treatment C4.5F3.5 achieved the highest value at 83.60 leaf, compared to C0F0, which achieved the lowest number at 55.40 leaves.

Table 3: The effect of foliar application with Chelated iron and Micro- max nutrient solution on leaves number (leaf plant⁻¹)

Nutrient solution C	Chelated iron levels F				Mean C
	F0	F2.5	F3.5	F4.5	
C0	55.40	60.23	61.83	60.37	59.46
C2.5	64.07	65.80	71.10	68.40	67.34
C3.5	70.50	72.43	75.73	75.00	73.42
C4.5	79.77	66.93	83.60	79.37	77.42
Mean F	67.43	66.35	73.07	70.78	
LSD0.05C= 3.40		LSD0.05F= 3.40		F = 6.81×LSD-0.05C	

Number of inflorescences per plant

The results indicated that the C4.5 treatment outperformed the other treatments, with the highest number of inflorescences per plant at 10.30, compared to C0, which gave the lowest results at 7.08 inflorescences plant⁻¹ (Table 4). The results also indicates that iron spraying in the F3.5 treatment resulted in 9.68 inflorescences plant⁻¹, compared to F0, which gave the lowest result at 7.63 inflorescences plant⁻¹. The results revealed a significant interaction between iron spraying and the nutrient solution. The C4.5F3.5 treatment recorded the highest value at 11.97 inflorescences plant⁻¹, while C0F0 gave the lowest result at 6.30 inflorescences plant⁻¹.

Table 4. The effect of foliar application with Chelated iron and Micro- max nutrient solution on number of in florescences plant⁻¹

Nutrient solution C	Chelated iron levels F				Mean C
	F0	F2.5	F3.5	F4.5	
C0	6.30	6.40	8.17	7.47	7.08
C2.5	7.87	8.23	8.23	7.17	7.88
C3.5	7.63	8.33	10.33	8.93	8.81
C4.5	9.50	9.27	11.97	10.47	10.30
Mean F	7.83	8.06	9.68	8.51	
LSD0.05C= 0.58		LSD0.05F= 0.58		F= 1.17×LSD-0.05C	

Number of flowers per florescences

The results in Table 5 show that the C4.5 treatment surpassed the other treatments, yielding the highest number of flowers per inflorescence at 15.86, while the C0 treatment recorded the lowest number at 8.52 flower. The results indicate that iron spraying in the F3.5 treatment resulted in 13.87 flower per inflorescence, compared to F0, which gave the lowest result at 10.12 flower. The result indicates a significant interaction between the two factors, the C4.5F3.5 treatment recorded the highest value at 16.27 flowers inflorescence-1, while C0F0 gave the lowest result at 7.37 flower.

Table 5: The effect of foliar application with Chelated iron and Micro- max nutrient solution on number of flower per inflorescences⁻¹

Nutrient solution C	Chelated iron levels F				Mean C
	F0	F2.5	F3.5	F4.5	
C0	7.37	7.40	10.07	9.23	8.52
C2.5	7.93	10.53	12.20	11.73	10.60
C3.5	10.70	14.03	16.27	15.20	14.05

C4.5	14.47	16.57	16.93	15.47	15.86
Mean F	10.12	12.13	13.87	12.91	
LSD0.05C= 0.84		LSD0.05F= 0.84		F= 1.69×LSD-0.05C	

Number of fruits Per plant

The results presented in Table 6 indicate that the C4.5 treatment exhibited superior performance compared to other treatments, with a maximum fruit yield of 22.75 fruits plant⁻¹, while the C0 treatment recorded the minimum yield of 16.67 fruits plant⁻¹. Similarly, iron application in the F3.5 treatment produced 23.08 fruits plant⁻¹, contrasted with the F0 treatment, which yielded the lowest count of 15.75 fruits plant⁻¹. The interaction between iron spraying and the nutrient solution in the C4.5F3.5 treatment resulted in the highest yield, with 28.00 fruits plant⁻¹, compared to the C0F0 treatment, which recorded the lowest yield of 13.67.

Table 6: The effect of foliar application with Chelated iron and Micro- max nutrient solution on number of fruits Per plant

Nutrient solution C	Chelated iron levels F				Mean C
	F0	F2.5	F3.5	F4.5	
C0	13.67	15.67	19.33	18.00	16.67
C2.5	18.00	16.33	24.00	20.33	19.67
C3.5	14.33	16.67	21.00	25.00	19.25
C4.5	17.00	22.33	28.00	23.67	22.75
Mean F	15.75	17.75	23.08	21.75	
LSD0.05C= 2.04		LSD0.05F= 2.04		F= 4.09×LSD0.05C	

Fruits diameter (mm)

The results in Table 7 show that the C4.5 treatment outperformed the other treatments, producing the largest fruit diameter at 37.53 mm, compared to the C0 treatment, which had the smallest diameter at 35.15 mm. The results indicates that iron spraying in the F3.5 treatment resulted in a fruit diameter of 42.61 mm, while the F0 treatment recorded the smallest diameter at 29.74 mm. The results indicate a significant Interaction between iron spraying and the nutrient solution; the C4.5F3.5 treatment achieved the highest fruit diameter at 48.00 mm, compared to the C0F0 treatment, which had the lowest diameter at 28.31 mm.

Table 7: The effect of foliar application with Chelated iron and Micro- max nutrient solution on fruits diameter (mm)

Nutrient solution C	Chelated iron levels F				Mean C
	F0	F2.5	F3.5	F4.5	
C0	28.31	32.49	40.24	39.56	35.15
C2.5	30.36	33.08	39.92	39.36	35.68
C3.5	30.61	34.55	42.28	39.96	36.85
C4.5	29.70	32.92	48.00	39.51	37.53
Mean F	29.74	33.26	42.61	39.60	
LSD0.05C= 1.77		LSD0.05F= 1.77		F= 3.54×LSD0.05C	

Fruits length (mm)

The results in Table 8 indicate that the C4.5 treatment resulted in the highest fruit length plant⁻¹, measuring 23.58 mm, compared to the C0 treatment, which recorded the lowest length at 21.42 mm. The results show that iron spraying in the F3.5 treatment produced a fruit length of 24.84 mm, while the F0 treatment recorded the smallest height at 19.80 mm fruit⁻¹. Regarding the interaction between the two factors, iron spraying and the nutrient solution, the C4.5F3.5 treatment achieved the highest fruit height at 27.12 mm, compared to the C0F0 treatment, which recorded the lowest height at 18.49 mm.

Table 8: The effect of foliar application with Chelated iron and Micro- max nutrient solution on fruits height (mm)

Nutrient solution C	Chelated Iron levels F				Mean
	F0	F2.5	F3.5	F4.5	C
C0	18.49	20.61	24.26	22.33	21.42
C2.5	20.19	22.03	24.25	21.75	22.06
C3.5	19.97	21.45	23.72	24.10	22.31
C4.5	20.54	21.86	27.12	24.80	23.58
Mean F	19.80	21.49	24.84	23.58	
LSD0.05C= 1.349		LSD0.05F= 1.349		F= N.S×LSD0.05C	

Total yield (tons per 500 square)

The results show that the C4.5 treatment outperformed the other treatments, producing the highest yield per greenhouse at 3.683 tons, compared to C0, which recorded the lowest yield at 2.074 tons (Table 9). The results indicate that iron spraying in the F3.5 treatment resulted in a yield of 3.511 tons, while the F0 treatment produced the lowest yield at 2.161 tons. The results revealed a significant interaction between the two factors; the C4.5F3.5 treatment achieved the highest yield at 4.607 tons, compared to the C0F0 treatment, which recorded the lowest yield at 1.760 ton plastic house⁻¹.

Table 9: The effect of foliar application with Chelated iron and Micro- max nutrient solution on total yield (tons per 500 square)

Nutrient solution C	Chelated iron levels F				Mean
	F0	F2.5	F3.5	F4.5	C
C0	1.760	2.117	2.257	2.163	2.074
C2.5	1.863	3.077	3.297	2.890	2.782
C3.5	2.343	3.057	3.883	3.653	3.234
C4.5	2.677	3.387	4.607	4.060	3.683
Mean F	2.161	2.909	3.511	3.192	
LSD0.05C= 0.267		LSD0.05F= 0.267		F= 0.534×LSD-0.05C	

Number of Flowers per plant

The results shown in Table 10 indicate that the treatment C4.5 outperformed the other treatments, providing the highest number flowers set 20.67 flower plant⁻¹, compared to C0, which gave the lowest results at 12.42 flower plant⁻¹. The same table shows that iron spraying in treatment F3.5 resulted in a plant height of 20.92 flower plant⁻¹, compared to F0, which gave the lowest results at 13.08 flower plant⁻¹.

Table 10: : The effect of foliar application with Chelated iron and Micro- max nutrient solution on Number of Flowers per plant

Nutrient solution C	Chelated iron levels F				Mean
	F0	F2.5	F3.5	F4.5	C
C0	8.67	9.67	17.00	14.33	12.42
C2.5	15.00	12.67	21.00	17.33	16.50
C3.5	12.33	13.67	21.33	19.33	16.67
C4.5	16.33	19.67	24.33	22.33	20.67
Mean F	13.08	13.92	20.92	18.33	
LSD0.05C= 2.28		LSD0.05F= 2.28		F= NS×LSD-0.05C	

Fruit weight (g).

The results shown in Table 11 indicate that the treatment C4.5 outperformed the other treatments, providing the highest number flowers set 157.7 g. plant⁻¹, compared to C0, which gave the lowest results at 125.7 g. plant⁻¹.

Table 11: The effect of foliar application with Chelated iron and Micro- max nutrient solution on Fruit weight (g).

Nutrient solution C	Chelated iron levels F				Mean C
	F0	F2.5	F3.5	F4.5	
C0	123.5	136.7	121.6	120.8	125.7
C2.5	139.4	169.3	142.6	144.5	149.0
C3.5	167.4	186.9	162.6	165.9	170.7
C4.5	162.8	138.3	165.2	164.5	157.7
Mean F	148.3	157.8	170.7	157.7	
LSD0.05C= 27.62		LSD0.05F=		F= N.S	
		N.S		×LSD0.05C	

Plant Yield (kg. plant⁻¹).

The results show that the C4.5 treatment outperformed the other treatments, producing the highest plant yield per greenhouse at 3685.2 g plant⁻¹ compared to C0, which recorded the lowest yield at 2074.2 g (Table 12). The results indicate that iron spraying in the F3.5 treatment resulted in a yield of 3505.8 g, while the F0 treatment produced the lowest yield at 2168.3 g. The results revealed a significant interaction between the two factors; the C4.5F3.5 treatment achieved the highest yield at 4556.7 g, compared to the C0F0 treatment, which recorded the lowest yield at 1760.0 g plant⁻¹

Table 12: The effect of foliar application with Chelated iron and Micro- max nutrient solution on Plant Yield (kg. plant⁻¹)

Nutrient solution C	Chelated iron levels F				Mean C
	F0	F2.5	F3.5	F4.5	
C0	1760.0	2116.7	2256.7	2163.3	2074.2
C2.5	1893.3	3076.7	3326.7	2923.3	2805.0
C3.5	2343.3	3056.7	3883.3	3800.0	3270.8
C4.5	2676.7	3386.7	4556.7	4120.7	3685.2
Mean F	2168.3	2909.2	3505.8	3251.8	
LSD0.05C= 269.8		LSD0.05F= 269.8		F= 539.6× LSD0.05C	

Discussion

The results indicate that foliar nutrient application had a clear positive effect on the vegetative and floral growth of tomato plants. Foliar feeding enhanced overall plant vigor, which promoted flower initiation. This improvement is attributed to increased carbon assimilation efficiency and the stimulation of auxin synthesis. Auxins, together with available phosphorus, are transported through the xylem to the axillary buds, leading to earlier flowering [12]. This superiority of foliar nutrients may also be attributed to the increased efficiency of fertilizers applied to the plant in a balanced manner, which plays a role in enhancing vegetative growth and increasing the number of floral buds on the plants [13]. Additionally, foliar spraying can be to greater carbon assimilation efficiency, thereby increasing carbohydrate content. This increase in carbohydrates is directly proportional to the formation of female flowers and the successful fruit set, due to the plant's improved carbohydrate content [4]. Chelated iron is essential for chlorophyll production, enzyme activation, and various metabolic processes. Its ability to participate in redox reactions makes it vital for photosynthesis and protein synthesis. Iron is also involved in the composition of cytochromes, which are crucial for photosynthesis, as well as in the formation of plant proteins. The effect of the research factors individually or collectively in increasing the number of flowers set, fruit weight and plant yield may be attributed to the role of both nitrogen and iron in their entry into the vital processes taking place inside the plant, which increases the effectiveness of the plant in carrying out the process of photosynthesis, which leads to increased vegetative growth of seedlings by increasing the rate of cell division and elongation and thus increasing the number of leaves. [14, 15]. These findings are consistent with the results of [16, 17, 18, 19, 20].

Conclusions

The study demonstrates that foliar application of Chelated iron and the nutrient solution (micro-max) Max significantly enhances both vegetative and reproductive growth in tomato plants. The treatments, particularly at higher concentrations (4.5 g L⁻¹ of Fe) and (4.5 g L⁻¹ of micro-mix), led to notable improvements in plant height, the number of inflorescences, flower formation, fruit size, and overall yield. The interaction between iron and the nutrient solution proved to be especially effective, resulting in the highest growth and yield. These findings suggest that the strategic use of foliar nutrients can optimize

the growth and productivity of tomato plants under plastic house conditions, making it a valuable practice for improving agricultural outcomes

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تأثير الرش بالحديد المخلبي والمحلول المغذي مايكرو ميكس على نمو وحاصل هجين الطمطة هايمر تحت ظروف البيوت البلاستيكية غير المدفأة

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قسم البستنة وهندسة الحدائق، كلية الزراعة، جامعة الانبار، الانبار، العراق¹

الخلاصة

نفذت التجربة في أحد البيوت البلاستيكية التابعة لكلية الزراعة / جامعة الانبار في الموسم الخريفي 2023 ، لدراسة تأثير بعض المغذيات في نمو وحاصل الطمطة هجين هايمر اشتملت التجربة على عاملين العامل الاول الرش بالحديد بأربعة تراكيز هي 0 و 2.5 و 3.5 و 4.5 غم لتر ماء-1. اما العامل الثاني رش المحلول المغذي *Micro mix* بأربعة تركيز هي 0 و 2.5 و 3.5 و 4.5 مل لتر ماء-1. نفذت التجربة العاملية ضمن تصميم القطاعات العشوائية الكاملة المعشاة *R.C.B.D* بواقع 16 معاملة وبثلاثة مكررات وفورنت المتوسطات حسب اختبار *L.S.D* على مستوى احتمال 0.05. تشير النتائج الى تفوق معاملة الرش بالمغذي المايكرو ماكس عند التركيز 4.5 مل لتر-1 والرش بالحديد عند التركيز 4.5 مل لتر-1 وتداخلهما في الصفات المدروسة اذ اعطت اعلى قيمة في ارتفاع النبات (180.0) و (171.5) وعدد الأوراق (77.42) و (73.07)، عدد النورات الزهرية (10.30) و (9.68) وعدد الازهار بالنورة (15.86) و (13.87) وعدد الثمار للنبات (22.75) و (23.08) وقطر الثمرة (37.53) و (42.61)، وطول الثمرة (23.58) و (24.84) والحاصل للبيت البلاستيكي (3.683) و (3.511) وعدد الازهار العاقدة ووزن الثمار وحاصل النبات على التوالي مقارنة مع معاملة القياس.

الكلمات المفتاحية: *Solanum lycopersicum L*، التسميد، المغذيات .