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Effects of Foliar Application of Fe-EDDHA, Power Mix Bio-fertilizer, and Casmocal on the Growth and Yield of Strawberry (Fragaria × ananassa Duch.) cv. 'Rubygem'

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ABSTRACT

This study was conducted from October 2022 to August 2023 at the College of Agricultural Engineering Sciences, University of Duhok, Kurdistan, Iraq, to determine the influence of foliar nutrient sprays on the vegetative growth, leaf mineral content, and yield traits of 'Rubygem' strawberry plants. The treatments included three concentrations of each factor, Casmocal (Ca) (0, 2 and 4 ml.L-1), Power Mix bio fertilizer(PM) (0, 2 and 5 ml.L-1), and iron (Fe) in the form of Fe-EDDHA (0, 40, and 80 mg.L-1). The results demonstrated that Casmocalat4ml.L-1significantly improved some parameters, including total leaf chlorophyll content, leaf area, leaves nutrient content (P, K and Ca %) and yield per plant. However, the highest leaf total chlorophyll, leaf area, leaf dry matter percentage%, leaf nutrient content (N%, K% and Femg.L-1) and yield per plant were recorded when high level of Power Mix (5ml.l-1) was sprayed. Fe at 80 mg.L-1enhanced (leaf total chlorophyll, leaf dry matter percentage, leaves nutrient content (N%, P%,Ca% and Fe mg.L-1)and yield per plant. Additionally, the findings indicated that combination of calcium, Power Mix and iron had optimized enhancement on the growth and productivity of “Rubygem” strawberry plants.

1.Introduction

Strawberry (Fragaria × ananassaDuch)is an important fruit of the genus Fragaria and belongs to the family Rosaceae. It is a high-yielding plant known for its excellent fruit quality, including flavor, color, and firmness(Hassan, 2002).However, strawberry production is highly dependent on proper nutrient management to enhance both vegetative growth and fruit yield (Singh et al., 2008).Since strawberries are extremely sensitive to nutritional balance, their nutritional state has a significant impact on their development, yield, and fruit quality (Mohamed et al., 2011). A high yield of high nutritional value and high quality is a result of appropriate fertilization. These factors improves plant resistance to fungal and insect infections as well as their tolerance to environmental, thermal, and water stress.

bio-stimulants such as Power Mix, which contains amino acids, organic acids, and uptake enhancers, has gained attention for improving plant growth, stress tolerance, and overall yield. These bio-stimulants play a crucial role in enhancing nutrient uptake, stimulating plant metabolism, and promoting resistance against abiotic stress conditions like drought, salinity, and temperature fluctuations (Colla et al., 2014).Studies have shown that amino acids in bio-stimulants act as precursors for hormone synthesis and enhance photosynthetic efficiency, leading to improved vegetative growth (Kirschbaum et al., 2019). Furthermore, organic acids promote increased fruit production and quality by enhancing rhizosphere nutrient mobility and root activity (Calvo et al., 2014).

Casmocal, a calcium-based product, is known to improve plant resistance to disease, enhance cell wall strength, and support proper fruit development (Mehraj et al., 2015). Calcium may have a beneficial effect through stimulating photosynthesis and controlling nitrogen metabolism(Gao et al., 2011). As calcium pectate builds the cell wall's structure, it also acts as a link between the cell wall's components and pectic acid, ensuring the plant's continuing growth and structural strength (Zhang et al., 2019a, Zhang et al., 2019b).According to Kazemi (2014), external calcium application improves strawberry plant fruit quality and increases leaf area, number, dry weight, and fruit weight. Mehraj et al. (2015)investigated how strawberry plants responded to foliage treatment of calcium oxide (CaO treatment at concentrations of 0, 50, and 100 ppm). The plants that were sprayed with 100mg l-1 resulted in the highest fruit number and weight. Ahmed et al. (2020) investigated the effects of 0.25 and 0.5% calcium chloride foliage spray on strawberry (Fragaria× ananassa Duch) var.“LiberationD'Orleans”growth, flowering, and yield. The plants when sprayed with 0.25% spraying the results showed there was a significant difference in the number of flowers per plant, total yield per plant, and total yield per experiment unit, and had the significant difference in average leaf area and number of leaves per plant when compared to the control.

Recently, the use of bio-stimulants such as Power Mix, which contains amino acids, organic acids, and uptake enhancers, has gained attention for improving plant growth, stress tolerance, and overall yield. These bio-stimulants play a crucial role in enhancing nutrient uptake, stimulating plant metabolism, and promoting resistance against abiotic stress conditions like drought, salinity, and temperature fluctuations (Colla et al., 2014).Studies have shown that amino acids in bio-stimulants act as precursors for hormone synthesis and enhance photosynthetic efficiency, leading to improved vegetative growth (Kirschbaum et al., 2019). Furthermore, organic acids promote increased fruit production and quality by enhancing rhizosphere nutrient mobility and root activity (Calvo et al., 2014).

Additionally, iron (Fe), when foliage spray in the form of Fe-EDDHA is crucial for chlorophyll production, photosynthesis, and overall plant vigor, particularly in plants growing in iron-deficient soils (Erdal et al., 2004). Many substances, like the cytochrome that is responsible for plant respiration, photosynthesis, and the synthesis of plant proteins, also include iron (Al-Mawsili, 2011). The most widely utilized form of iron is chelated iron, and they also keep the element in a soft form that plants may absorb and transfer. Fe-EDTA are chelating chemicals commonly used on many different plants (Mohamed et al., 2011).

In another study, foliar spraying on a williams'spear cultivar with amino-acid chelated-Fe reduced the symptoms of a Fe deficit and raised overall yield by 47% and leaf Fe content by 120% (Köksal et al., 1999).According to Almaliotis et al. (2000), a significant linear association existed between Fe concentration and yield of strawberry. Similarly, foliar Fe fertilization improved the quality of strawberry fruit, according to (Karp et al., 2000).In strawberries, Fe-EDDHA has been found to significantly improve plant vigor, fruit size, and yield, particularly in iron-deficient soils. The application of Fe-EDDHA can prevent chlorosis, restore leaf greenness to leaves, and increase photosynthetic activity, all of which contribute to enhanced growth and yield (Erdal et al., 2004). Moreover, adequate iron levels are crucial for maintaining a healthy root system, which is efficient nutrient and water uptake, further boosting growth and productivity of plant (Gramss and Voigt, 2013).

The region of Kurdistan is ideal for growing strawberries, but because of issues with its soil, such as a high pH and a lack of organic matter, it lacks micronutrients, especially iron and a few other elements. Due to this problem, farmers are now using biofertilizers to feed their plants and developing alternatives to chemical fertilizers. Such methods can lower environmental pollution and health problems while also increasing soil fertility by enhancing its nutritional components and soil microbial biodiversity. According to Akanbi et al. (2010)and Ainika et al. (2012), this will result in safer and healthier food items and agricultural methods in addition to increased plant productivity. Therefore, the aim of this study is to evaluate the individual and combined effects of these treatments Casmocal (Ca), biofertilizer (Power Mix), and Fe-EDDHA on the growth and yield characteristics of strawberry cv. "Rubygem"

2. Materials and Methods

This study was conducted from October 2022 to August 2023 at the College of Agricultural Engineering Sciences, University of Duhok, Kurdistan region, Iraq, the experimental site is located in Sumel city at latitude of 36° 51' 38.077" N, longitude of 42° 52' 02.998" E, and an elevation of 473m above sea level. The study consist of three factors, first ; Casmocal(calcium CaO 28%)at (0, 2 and 4 $ml.L^{-1}$), second; Power Mix(30% nutrient element, organic acids and growth stimulators) at(0, 2, 5 $ml.L^{-1}$) and third; Fe-EDDHA (at 0, 40, and 80 $mg·L^{-1}$) on the growth and yield characteristics of strawberry "Rubygem" cultivar.

3. Results and Discussion

3.1. Leaf Chlorophyll (SPAD unit)

Results in table (1) clarified that increasing levels of calcium (Ca) generally result in a higher chlorophyll content, maximum effect of Ca is (43.07) indicating the most significant improvement in chlorophyll content with higher calcium levels (4ml l-1), as well as increasing the power mix (P.M.) also contributes to higher chlorophyll content with a noticeable improvement across the Fe treatments with the best results observed at 80 mg. L-1.

There are notable interactive effects among calcium, power mix, and iron, which collectively enhance leaf chlorophyll content. In which the interaction of Ca and P.M. shows improved chlorophyll content at higher levels. The effect of Ca*Fe is observed across varying combinations, with the best interaction being (43.85) at 2ml.L-1Ca with 0 mg. L-1Fe.The highest chlorophyll content (47.00) was achieved under a triple combination of high calcium 4ml.L-1Ca, and 5ml.L-1 levels of P.M. without Fe concentration, while the lowest value was achieved (26.17) from untreated plants (control treatment).

Table1. Effect of Casmocal, Power Mix, Fe-EDDHA and their interactions on leaf Chlorophyll content (SPAD unit) of strawberry plant.

Casmocal($ml.l^{-1}$)	Power mix($ml.l^{-1}$)	Fe-EDDHA ($mg.l^{-1}$)			Casmocal*Power Mix	Effect of Casmocal
		0	40	80		
0	0	26.17i	40.70d-h	42.02b-g	36.30f	38.33b
	2	37.60h	38.15gh	39.17e-h	38.31e	
	5	41.74b-g	39.85e-h	39.53e-h	40.37d	
2	0	44.90a-c	45.25ab	41.08c-h	43.74ab	42.25a
	2	41.20b-h	41.15b-h	43.53a-e	41.96b-d	
	5	41.05c-h	41.15b-h	40.95c-h	41.05cd	
4	0	41.75b-g	39.20f-h	44.80a-d	41.92b-d	43.07a
	2	42.80b-f	43.40a-e	42.53b-f	42.91a-c	
	5	47.00a	42.15b-h	44.00a-d	44.38a	
Casmocal*Fe-EDDHA	0	35.17e	39.57d	40.24cd	Effect of power mix	
	2	42.38ab	42.52ab	41.86a-c		
	4	43.85a	41.58b-d	43.78a		
Power mix*Fe-EDDHA	0	37.61c	41.72ab	42.63ab	40.65b	
	2	40.53b	40.90b	41.74ab	41.06ab	
	5	43.26a	41.05ab	41.49ab	41.94a	
Effect of Fe-EDDHA		40.47b	41.22ab	41.96a		

*Within a column, rows that have the same latter indicated that each factor and their interaction are not significantly different according to Duncan Multiple range test at the 0.05probability level

3.2. Leaf area (cm2)

Table (2) shows that increasing calcium levels positively influences leaf area, which maximum level (Ca) is (38.86 cm2) was in 4 ml.l-1, resulting that higher calcium concentrations result in larger leaf areas. In addition, higher levels of power mix also increase the leaf area. However, gave best result. Fe treatments had no significant effect. Concerning the interaction between calcium and power mix (Ca*PM) shows maximum leaf area (40.41cm2) at higher levels. The combinations of Ca*Fe and PM*Fe enhance leaf area, particularly at higher levels of calcium, power mix and Fe. The combination of 0 ml.L-1Ca with5ml.L-1 PM and 0 mg.L-1 Fe results in the largest leaf area (44.03 cm2).

3.3 leaf Dry Matter (%)

The table (3) presents how calcium (Ca), power mix (PM), and iron (Fe) affect the dry matter content of strawberry plant. Calcium levels had no significant levels on leaf dry matter. Concerning the effect of Power Mix (PM) notable significant improvements by using PM at 5 ml.L-1levels in which reached (32.86%) over control treatment. Also iron concentration at 80 mg.L-1recorded the best dry matter (32.92%). Concerning the binary interaction between calcium and power mix (Ca*PM) shows enhanced dry matter percentage, with the best combination reaching (33.80%) at 4 ml.L-1Caand 5 ml.L-1PM respectively. The optimal treatment for maximizing dry matter 4 ml.L-1Cawith 5ml.L-1power mix and 80 mg.L-1 Fe interaction treatment(34.86%).

Table2. Effect of Casmocal, Power Mix, Fe-EDDHA and their interactions on leaf area (cm^2) of strawberry plant.

Casmocal($ml.l^{-1}$)	Power mix($ml.l^{-1}$)	Fe-EDDHA($mg.l^{-1}$)			Casmocal* Power mix	Effect of Casmocal
		0	40	80		
0	0	27.04h	35.32c-g	33.20c-g	31.85c	34.83b
	2	32.59d-g	34.83c-g	33.18c-g	33.53c	
	5	44.03a	35.50c-g	37.78b-d	39.10ab	
2	0	31.01f-h	32.39e-g	32.84d-g	32.08c	33.21c
	2	33.16c-g	36.05c-f	30.44gh	33.22c	
	5	38.32bc	31.31f-h	33.38c-g	34.34c	
4	0	37.68b-d	42.01ab	37.05b-e	38.91ab	38.86a
	2	37.05b-e	38.20bc	36.55c-e	37.27b	
	5	41.89ab	37.66b-d	41.66ab	40.41a	
Casmocal* Fe-EDDHA	0	34.55bc	35.21b	34.72bc	Effect of Power mix	
	2	34.16bc	33.25bc	32.22c		
	4	38.87a	39.29a	38.42a		
Power mix * Fe-EDDHA	0	31.91e	36.57bc	34.36c-e	34.28b	
	2	34.27c-e	36.36bc	33.39de	34.67b	
	5	41.41a	34.82cd	37.61b	37.95a	
Effect of Fe-EDDHA		35.86a	35.92a	35.12a		

*Within a column, rows that have the same latter indicated that each factor and their interaction are not significantly different according to Duncan Multiple range test at the 0.05probability level.

Table3. Effect of Casmocal, Power Mix, Fe-EDDHA and their interactions on leaf dry matter % of strawberry plant.

Casmocal($ml.l^{-1}$)	Power mix($ml.l^{-1}$)	Fe-EDDHA($mg.l^{-1}$)			Casmocal* Power mix	Effect of Casmocal
		0	40	80		
0	0	30.84b-e	31.10b-e	30.52c-e	30.82c	32.26a
	2	32.33a-e	33.33a-d	33.33a-d	33.00ab	
	5	33.33a-d	33.33a-d	32.16a-e	32.94ab	
2	0	30.33c-e	32.96a-e	33.21a-d	32.17 ab	32.26a
	2	32.37a-e	34.37ab	31.59a-e	32.78ab	
	5	29.98de	31.81a-e	33.69a-c	31.83bc	
4	0	30.52c-e	29.39 e	33.81a-c	31.24bc	32.35a
	2	30.58c-e	32.34a-e	33.09a-d	32.00a-c	
	5	33.33a-d	33.22a-d	34.86a	33.80a	
Casmocal* Fe-EDDHA	0	32.17a-c	32.59a-c	32.01a-c	Effect of Power mix	
	2	30.90bc	33.05ab	32.83a-c		
	4	31.48bc	31.65bc	33.92a		
Power mix *Fe	0	30.57c	31.15bc	32.52ab	31.41b	
	2	31.76a-c	33.35a	32.67ab	32.59a	
	5	32.22a-c	32.79ab	33.57a	32.86a	
Effect of Fe-EDDHA		31.52b	32.43ab	32.92a		

*Within a column, rows that have the same latter indicated that each factor and their interaction are not significantly different according to Duncan Multiple range test at the 0.05probability level.

3.4. Leaf nitrogen content (%)

Results in table (4) clarified that calcium application led to an improvement in leaf nitrogen content over control treatment. The level of calcium was most significant at higher levels (2 and 4 ml.L-1), resulting higher significant average of nitrogen content (1.49%). Whereas, Power mix application showed a positive trend in enhancing leaf nitrogen levels, particularly at 5 ml.L-1, with the highest nitrogen content averaging (1.50%), however foliage spray of iron of both 40 and 80 mg.L-1increased significant nitrogen content (1.45 and 1.46% respectively) over control treatment. The combination of 2 ml.L-1Cawith 40 mg.L-1 Fe resulted in relatively higher nitrogen levels (1.60%). Casmocol and power mix combination had no clear effect on nitrogen content, however the combination of 2 ml.L-1Cawith both 2 and 5 ml.L-1power mix gave highest results(1.52%). Use a combination of 2ml.L-1 calcium + 5 ml.L-1 power mix + 40 mg.L-1 iron to maximize nitrogen content in strawberry leaves which achieved (1.73%) value.

Table4. Effect of Casmocal, Power Mix, Fe-EDDHA and their interactions on leaf nitrogen content (%) of strawberry plant.

Casmocal(ml.l^{-1})	Power mix(ml.l^{-1})	Fe-EDDHA(mg.l^{-1})			Casmocal* power mix	Effect of Casmocal
		0	40	80		
0	0	0.92l	1.22k	1.41f-h	1.18d	1.35c
	2	1.27jh	1.41f-h	1.42fg	1.37c	
	5	1.53cd	1.31ij	1.65b	1.49a	
2	0	1.30ij	1.54c	1.43f	1.42b	1.49a
	2	1.35i	1.54c	1.66b	1.52a	
	5	1.42fg	1.73a	1.43f	1.52a	
4	0	1.61b	1.33ij	1.36hi	1.43b	1.46b
	2	1.51c-e	1.45ef	1.36g-i	1.44b	
	5	1.47d-f	1.54c	1.46ef	1.49a	
Casmocal* Fe-EDDHA	0	1.24h	1.31g	1.49c	Effect of Power mix	
	2	1.36f	1.60a	1.50bc		
	4	1.53b	1.44d	1.39e		
Power mix * Fe-EDDHA	0	1.28f	1.36e	1.40d	1.35c	
	2	1.38de	1.47c	1.48bc	1.44b	
	5	1.47c	1.52a	1.51a	1.50a	
Effect of Fe-EDDHA		1.38b	1.45a	1.46a		

*Within a column, rows that have the same latter indicated that each factor and their interaction are not significantly different according to Duncan Multiple range test at the 0.05probability level.

3.5. Leaf phosphorus content (%)

Table (5) clearly shows that increasing calcium levels positively influenced leaf phosphorus content, the highest phosphorus content was observed at 4ml.L-1Ca with an average of (0.54%). Whereas, power mix levels showed improvement in leaf phosphorus content. The phosphorus content increased with higher Fe levels, reaching its maximum at 80 mg.L^{-1} Fe, with an average of (0.57%). In the interaction between calcium and power mix significantly improved leaf phosphorus content, particularly at 0 ml.L^{-1}Ca combined with 2 ml.L^{-1} PM (0.61%). The combination of 0 ml.L^{-1}Ca with 80 mg.L^{-1} Fe resulted in on highest phosphorus value (0.65%).The highest phosphorus content (0.63%) was achieved with 5 ml.L-1 PM and 80 mg.L-1 Fe, demonstrating the synergy between power mix and iron.Apply0 ml.L^{-1} calcium, with 2ml.L^{-1} PM and 80 mg.L-1Fe (0.85%) to achieve highest phosphorus content in strawberry leaves.

Table5. Effect of Casmocal, Power Mix, Fe-EDDHA and their interactions on leaf phosphorus content (%) of strawberry plant.

Casmocal(ml.l^{-1})	Power mix(ml.l^{-1})	Fe-EDDHA (mg.l^{-1})			Casmocal* Power mix	Effect of Casmocal
		0	40	80		
0	0	0.25j	0.53de	0.48f-h	0.42e	0.52b
	2	0.54de	0.44h	0.85a	0.61a	
	5	0.54de	0.45gh	0.63c	0.54c	
2	0	0.52d-f	0.39i	0.52d-f	0.48d	0.53b
	2	0.63c	0.51d-f	0.44h	0.53c	
	5	0.55de	0.53de	0.64c	0.57b	
4	0	0.72b	0.46gh	0.46gh	0.55c	0.54a
	2	0.55de	0.55de	0.50e-g	0.53c	
	5	0.46gh	0.56d	0.63c	0.55c	
Casmocal* Fe-EDDHA	0	0.44e	0.47d	0.65a	Effect of Power mix	
	2	0.56b	0.48d	0.54c		
	4	0.57b	0.52c	0.53c		
Power mix * Fe-EDDHA	0	0.49c	0.46d	0.49c	0.48b	
	2	0.57b	0.50c	0.60b	0.56a	
	5	0.52c	0.51c	0.63a	0.55a	
Effect of Fe		0.53b	0.49c	0.57a		

*Within a column, rows that have the same latter indicated that each factor and their interaction are not significantly different according to Duncan Multiple range test at the 0.05probability level.

3.6. Leaf potassium content (%)

Table (6) explained that calcium significantly increased leaf potassium content, with the highest effect observed at 4 ml.L-1Ca (1.23%).The power mix also had a significant effect, with the 5 ml.L-1 treatment achieving the highest average potassium content (1.22%). However, increasing Fe levels consistently improved potassium content, with 40 mg.L-1 Fe achieving the highest average of potassium (1.21%). The interaction between calcium and power mix levels showed the highest potassium content (1.27%) at 0 ml.L-1Ca and 5 ml.L-1PM.Thecombination of 4 ml.L-1Ca and 40, 80 mg.L-1 Fe produced a high potassium level (1.26%), highlighting the synergistic effect between these treatments. The interaction of 2ml.L-1 P.M. with 80 mg.L-1 Fe , and 5ml.L-1 P.M. with 40 mg.L-1highest K value (1.26%).

The triple combination of calcium, power mix, and iron significantly influenced leaf potassium content in strawberry. The most effective treatments (1.41 and 1.40%) at 4ml.L-1Ca combinationof0ml.L-1 P.M. and 40 mg.L-1 Fe respectively.

Table6. Effect of Casmocal, Power Mix, Fe-EDDHA and their interactions on leaf potassium content (%) of strawberry plant.

Casmocal(ml.l^{-1})	Power mix(ml.l^{-1})	Fe-EDDHA(mg.l^{-1})			Casmocal* Power mix	Effect of Casmocal
		0	40	80		
0	0	0.96h	1.19c-e	1.07g	1.07e	1.18c
	2	1.24c	1.07g	1.32b	1.21b	
	5	1.32b	1.40a	1.08g	1.27a	
2	0	1.18de	1.04g	1.09g	1.10d	1.13b

	2	1.08g	1.13f	1.14ef	1.12d	
	5	1.14ef	1.24c	1.15ef	1.18c	
4	0	1.14ef	1.41a	1.14ef	1.23b	1.23a
	2	1.17d-f	1.22cd	1.32b	1.23b	
	5	1.19c-e	1.16ef	1.32b	1.22b	
Casmocal* Fe-EDDHA	0	1.17c	1.22b	1.16d	**Effect of Power mix**	
	2	1.13ef	1.14d-f	1.13ef		
	4	1.17c	1.26a	1.26a		
Power mix * Fe-EDDHA	0	1.09e	1.21b	1.10e	1.14c	
	2	1.16cd	1.14d	1.26a	1.19b	
	5	1.22b	1.26a	1.18c	1.22a	
Effect of Fe-EDDHA		1.16c	1.21a	1.18b		

*Within a column, rows that have the same latter indicated that each factor and their interaction are not significantly different according to Duncan Multiple range test at the 0.05probability level.

3.7. Leaf Fe content (mg.L-1)

Results in Table (7) illustrated that calcium application decreased significantly leaf Fe content. That 0 ml.L-1Ca treatment resulted in the highest average Fe content (165.80 mg. l-1), while 4 ml.L-1Ca resulted in the lowest (130.51mg. l-1). While foliar spraying with power mix significantly influenced Fe content in strawberry leaves. The 5 ml.L-1 PM treatment achieved the highest Fe content (162.25mg.l-1) followed by 0 ml.L-1 (153.16 mg.l-1). Lower PM concentration (2 ml.L-1) PM resulted in the lowest Fe levels (140.16mg.l-1). However, increasing Fe levels in the treatment enhanced leaf Fe content, the highest Fe content was observed at 80 mg.L-1 Fe (160.58mg.l-1), but the lowest content was at 0 mg.L-1 Fe (143.18mg. l-1). The highest leaves Fe content (190.84mg. l-1) was achieved with the combination of 2ml.L-1Cawith 0ml.L-1 PM whereas (177.71mg. l-1) Fe level was achieved with the combination of 0 ml.L-1Ca with 80 mg.L-1 Fe, and (171.60 mg.l-1) Fe level was recorded from the interaction between 5ml.L-1 PM*40 mg.L-1 Fe. Concerning the triple interaction of Ca, P.M. and Fe demonstrated that the combination of 2 ml.L-1Ca, 0ml.L-1 PM with 80 mg.L^{-1} Fe yielded the highest Fe content (210.16mg. l-1).

3.8. Leaf calcium content (%)

Table (8) illustrates that, in compration to other treatments, the application of 4 ml.L-1Ca produced the highest leaf Ca content (1.15%).The lowest leaf Ca content was observed with 0 ml.L-1Ca (1.13%), confirming the necessity of calcium supplementation. The 2 ml.L-1 PM treatment resulted in the highest leaf Ca content (1.17%) whereas the lowest Ca content was observed with 0 ml.L-1 PM (1.07%). Increasing Fe concentrations positively impacted Ca content, that 80 mg L-1 Fe yielding the highest average (1.18%), the lowest Ca content was at 0 mg L-1 Fe (1.04%).

Table7. Effect of Casmocal, Power Mix, Fe-EDDHA and their interactions on leaf Fe content (mg.L^{-1}) of strawberry plant.

Casmocal(ml.l^{-1})	Power mix(ml.l^{-1})	Fe-EDDHA (mg.l^{-1})			Casmocal* power mix	Effect of Casmocal
		0	40	80		
0	0	91.58l	195.61b	183.00d	156.73e	165.80a
	2	194.38b	145.80g	175.33e	171.84b	
	5	147.60g	184.13d	174.81e	168.85c	
2	0	188.79c	173.57e	210.16a	190.84a	159.25b
	2	144.14g	107.59k	134.76h	128.83f	
	5	146.49g	174.20e	153.61f	158.10de	
4	0	115.75j	105.90k	114.05j	111.90h	130.51c

	2	113.37j	123.02i	123.08i	119.83g	
	5	146.52g	156.48f	176.45e	159.81d	
Casmocal* Fe-EDDHA	0	144.52e	175.18a	177.71a	Effect of Power mix	
	2	159.80c	151.78d	166.18b		
	4	125.21h	128.47g	137.86f		
Power mix * Fe-EDDHA	0	132.04f	158.36c	169.07ab	153.16b	
	2	150.63d	125.47g	144.39e	140.16c	
	5	146.87e	171.60a	168.29b	162.25a	
Effect of Fe-EDDHA		143.18c	151.81b	160.58a		

*Within a column, rows that have the same latter indicated that each factor and their interaction are not significantly different according to Duncan Multiple range test at the 0.05probability level.

Concerning the interaction effect of Ca with PM, 0 ml.L-1Ca and 2 ml.L-1 PM record the highest value (1.27%). The highest Ca content was achieved with the combination of 4 ml.L-1Ca and 80 mg.L-1 Fe (1.26%), showing synergistic effects. While the interaction of 2ml.L-1 P.M. with 80 mg.L-1 Fe resulted in relatively high Ca content (1.24%). Whereas the treatment of interaction among 0 ml.L-1Ca, 2ml L-1 P.M. and 80 mg.L-1 Fe resulted in relatively high Ca content (1.41%), showing an effective combination for enhancing calcium uptake.

3.9. Fruit weight (g)

Results in table (9) illustrated that foliar spray of various Ca and Fe concentrations did not affect significantly on fruit weight, whereas PM 2ml.L-1 recorded the highest value of fruit weight (8.82g) correspondingly in comparison to other treatments. Interaction between calcium and power mix together significantly boost fruit weight, with a maximum value of (9.68g)observed at 4 ml.L-1Ca and 2ml.L-1PM. Regarding the combined use of Ca and Fe also increases fruit weightat4ml.L-1Ca with 40mg.L-1Fe level (9.71g) was received. Interaction of PM and Fe show synergistic effects, with a highest notable enhancement in fruit weight(9.10g) at 2ml.L-1PM with 80mg.l-1Fe level and (9.09 g)at 2ml.L-1PM with 40 mg.l-1Fe level. The highest fruit weight (10.85g) is achieved with 2ml.L-1Ca+0ml.L-1P.M. +40 mg.L-1 Fe combination treatment.

Table8. Effect of Casmocal, Power Mix, Fe-EDDHA and their interactions on leaf calcium content (%) of strawberry plant.

Casmocal(ml.l^{-1})	Power mix(ml.l^{-1})	Fe-EDDHA (mg.l^{-1})			Casmocal* power mix	Effect of Casmocal
		0	40	80		
0	0	0.58i	1.02e-h	1.15b-h	0.92e	1.13ab
	2	1.23a-e	1.19b-g	1.41a	1.27a	
	5	1.27ab	1.24a-d	1.04e-h	1.18ab	
2	0	1.00f-h	1.22a-e	1.24a-d	1.16bc	1.08b
	2	1.06c-h	1.04d-h	1.07b-h	1.06cd	
	5	1.09e-h	1.02e-h	0.98h	1.03d	
4	0	0.99h	1.15b-h	1.27ab	1.13bc	1.15a
	2	1.05e-h	1.20b-f	1.26a-c	1.17b	
	5	1.14b-h	1.05e-h	1.25a-c	1.14bc	
Casmocal* Fe-EDDHA	0	1.02d	1.15bc	1.20ab	Effect of power mix	
	2	1.05cd	1.09b-d	1.10		
	4	1.06cd	1.13b-d	1.26a		
Power mix *	0	0.86d	1.13bc	1.22ab	1.07b	

Fe-EDDHA	2	1.11c	1.14a-c	1.24a	1.17a
	5	1.16a-c	1.10c	1.09c	1.12ab
Effect of Fe-EDDHA		1.04c	1.13b	1.18a	

*Within a column, rows that have the same latter indicated that each factor and their interaction are not significantly different according to Duncan Multiple range test at the 0.05probability level.

Table9. Effect of Casmocal, Power Mix, Fe-EDDHA and their interactions on Fruit weight (g) of strawberry plant.

Casmocal(ml.l^{-1})	Power mix(ml.l^{-1})	Fe-EDDHA(mg.l^{-1}) 0	40	80	Casmocal* Power mix	Effect of Casmocal
0	0	7.38f-h	8.27c-h	7.88e-h	7.85cd	8.46a
	2	8.39c-h	8.32c-h	8.11e-h	8.27b-d	
	5	10.15a-d	8.91b-g	8.72c-g	9.26ab	
2	0	7.91e-h	10.85a	7.47f-h	8.74a-c	8.37a
	2	6.64h	10.22a-c	8.70b-g	8.52bc	
	5	7.71f-h	8.07e-h	7.72f-h	7.83cd	
4	0	7.65f-h	6.95gh	7.61f-h	7.40d	8.51a
	2	9.81a-e	8.73b-g	10.49ab	9.68a	
	5	8.99a-f	8.15e-h	8.24d-h	8.46b-d	
Casmocal* Fe-EDDHA	0	8.64b	8.50b	8.24bc	Effect of Power mix	
	2	7.42c	9.71a	7.96bc		
	4	8.82ab	7.94bc	8.78ab		
Power mix * Fe-EDDHA	0	7.65b	8.69ab	7.65b	8.00b	
	2	8.28ab	9.09a	9.10a	8.82a	
	5	8.95ab	8.38ab	8.22ab	8.52ab	
Effect of Fe-EDDHA		8.29a	8.72a	8.33a		

*Within a column, rows that have the same latter indicated that each factor and their interaction are not significantly different according to Duncan Multiple rangetest at the 0.05probability level.

3.10. Yield per plant (g. plant-1)

Results in table (10) shows that increasing calcium levels up to (4 ml.L-1) results in a significant improvement in yield. The maximum effect of calcium (Ca) is (180.18g). Also the application of the power mix at (5ml.L-1) increases yield up to (173.52g).Whereas concentrations (40, and 80mg.Fe L-1) improve yield, with the best effect observed at 40 mg. Fe L-1 (169.83g).Fe concentration had no significant effect on yield per plant. Interaction between Ca and PM significantly led to increases the yield at levels of 4 ml.L-1Ca with 2 ml.L-1PMwith the highest value of (204.75g) was observed. Interaction among Ca*Fe positively impact yield, especially at 4 ml.L-1Cawith 80 mg.L-1Fe (191.47g). The combined use of power mix and iron also enhances yield at 2 ml.L-1PM. with 80 mg.L-1 Fein which (188.00g) was recorded. The highest yield (233.99) is achieved with 4 ml.L-1Ca, 2 ml.L-1PM., and 80 mg.L-1 Fe, demonstrating the optimal combination for maximizing yield per plant. Whereas control treatment gave the lowest yield value (115.97g).

Table10. Effect of Casmocal, Power Mix, Fe-EDDHA and their interactions on yield(g plant^{-1}) of strawberry plant.

Casmocal(ml.l^{-1})	Power Mix(ml.l^{-1})	Fe-EDDHA (mg.l^{-1})			Casmocal* Power Mix	Effect of Casmocal
		0	40	80		
0	0	115.97j	157.60c-i	130.95ij	134.84e	155.83b
	2	152.94e-i	144.49h-j	155.12c-i	150.85de	
	5	188.00b-e	190.57bc	166.87b-h	181.81b	
2	0	184.13b-e	172.59b-h	147.70f-j	168.14b-d	165.20b
	2	154.47d-i	182.66b-f	174.88b-h	170.67bc	
	5	142.44h-j	162.64c-i	165.27b-i	156.79cd	
4	0	159.66c-i	146.09g-j	155.77c-i	153.84cd	180.18a
	2	180.56b-g	199.69b	233.99a	204.75a	
	5	189.11b-d	172.13b-h	184.66b-e	181.96b	
Casmocal* Fe-EDDHA	0	152.30c	164.22bc	150.98c	Effect of Power Mix	
	2	160.35bc	172.63b	162.62bc		
	4	176.44ab	172.64b	191.47a		
Power Mix * Fe-EDDHA	0	153.25c	158.76bc	144.80c	152.27b	
	2	162.66bc	175.62ab	188.00a	175.42a	
	5	173.18ab	175.11ab	172.27ab	173.52a	
Effect of Fe-EDDHA		163.03a	169.83a	168.36a		

*Within a column, rows that have the same latter indicated that each factor and their interaction are not significantly different according to Duncan Multiple rangetest at the 0.05probability level.

4. Discussion

According to the results, it appears that spraying treatments enhanced most of the study's parameters. Casmocal foliar spraying produced the highest significant values for vegetative growth characteristics (leaf area and chlorophyll content in the leaves); this could be because calcium plays a role in cell division, elongation and strength, middle platelet composition, and cell water balance (Ali and Majeed, 2023). Although calcium is one of the essential components inter in the structure of cell walls and membranes, it is necessary for controlling growth and development in plants. Similar trends were observed by these which are in agreement with Hamail et al. (2018)on the strawberry plant. Ca plays an essential role in the permeability of the plasma membranes and is necessary for the processes of cell division and growth. These processes directly affect the plant's growth and fruit production. The increase in yield, however, is because calcium plays a part in the formation of cell walls in addition to entering the synthesis of cellular membranes and regulating their permeability (Cakmak, 2014). The previously mentioned findings are consistent with those of studies by Singh et al. (2007),Hussein et al. (2017).

The results demonstrate that this materialsuperior other fertilizers in most of parameters, including dry matter, leaf area, and leaf chlorophyll content. The accumulation of macronutrients (N, P, and K) in the leaves as a result of applying various fertilizers is probably the cause of these results. These elements play a key role in the production of proteins, amino acids, enzymes, chlorophyll, and in the process of photosynthesis, and the rate at which carbohydrates are assimilated. Plant growth chemicals such as IAA and GA help them elongate and divide their cells, which promotes vegetative development (Rathi and Bist, 2004, Kumar et al., 2015). The results reported were comparable to those of (Hassan, 2015 andKumar et al. 2015).

Furthermore, it appears that the application of power mix has enhanced the nutrients' availability to plant roots. Because nutrients were available, plant growth was improved and yield increased. Khalil (2014) and Glinicki et al. (2011) also found comparable results. They found that the development of strawberry plants was significantly impacted by both commercial mineral fertilizer and biofertilizer. The bioactivities of plants, especially in the process of photosynthesis, reflected this increase in nutrients, which enhanced the plants' vegetative development. As a result, there were more fruits per plant, the fruits weighed more, and the total yield increased (Mengel and Kirkby, 1987). According to the results, foliar Fe application is a successful method of raising Fe concentrations in strawberry cultivars(Erdal et al., 2004).The increase in indicators of vegetative growth when chelated iron is sprayed on plants may be due to the iron's essential role in oxidative and reductive enzyme breakdown as well as improved enzymatic activities that aid in enhancing physiological processes(Gondal et al., 2023 and Gheshlaghi et al., 2023).

5. Conclusion.

Based on the results in this study it was found that the growth and yield of Fragaria × ananassa cv. Rubygemsignificantly influenced by the foliar spray with Casmocal,especiallyat (4ml.L-1), Power Mix (5ml.L-1) and Fe at (80 mg.L-1)led to a significant increase in mostly studied characters.It is highly recommended toavoid using higher calcium concentrations as they may reduce Fe content due to antagonistic effects.The synergistic application of these treatments offers promising potential for improving strawberry growth, yield, and fruit quality, ultimately contributing to more sustainable and efficient strawberry production.

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Conflict of Interest

The authors state that there are no conflicts of interest with the publication of this work.

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