International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 1s, 2025
https://www.theaspd.com/ijes.php

Effect of foliar spray with iron and zinc on the growth and yield of strawberry plants

Faris, F. A. Al-Zuhairi[1], Jassim M.A. Al-A'Areji[2], Ahmed T. Al-Abbasi[2]
[1] Department of Desertification Control Technologies/ College of Agricultural Technology/ Northern Technical University/ Iraq
[2] Hort.& Landscape Design/College of Agriculture and Forestry/Mosul University/ Iraq

ABSTRACT: The present investigation was carried out during the 2023-2024 season in unheated polyhouse belong to The Department of Horticulture and Landscape Design, which is part of the College of Agriculture and Forestry at the University of Mosul, is located in Nineveh Governorate., to study the effect of foliar spray with iron and zinc on the growth and yield of strawberry plant (*Fragaria × ananassa* Duch.) cv. Albion. The experiment was laid out in Randomized Complete Block Design (RCBD) with two factors (iron and zinc) as foliar spray, four concentrations of Fe (0,10,20, 30 mg Fe L^{-1})by using Fe-EDDHA(6% Fe) and three concentrations of Zn(0,150,200 mg Zn L^{-1})by using ZnEDTA(12% Zn), each alone or with each other, with the experiment was conducted with three replicates and eight plants per experimental unit.. The plants were sprayed three times with iron and zinc. Results showed that the that foliar spray of iron at the three concentrations (10, 20 and 30 mg L^{-1}) significantly increased all the studied traits (leaves chlorophyll, number of leaves per plant, leaf area, number of runners, number of fruits, fruit weight, length and width of the fruit and plant yield), as compared with control, while the concentration of 30 mg L^{-1} gave the highest means of all traits, However, the foliar spray of zinc at 150 and 200 mg L^{-1} concentrations led to a significant increase in all studied traits compared to the control treatment, but 200 mg Zn L^{-1} was significantly superior and gave the highest values in all traits. All the attributes studied were significantly affected by the interaction between iron and zinc, and the best values of all studied parameters had been executed with the treatment of 30 mg Fe L^{-1} + 200 mg Zn L^{-1}.

Keywords: strawberry, iron, zinc, leaves area, fruits, yield.

INTRODUCTION

Strawberry plants (*Fragaria × ananassa* Duch.) produce one of the most popular and consumed fruits globally, known for their sweet and savory taste and high nutritional value. Strawberries belong to the Rosaceae family, which includes many economically important fruits such as apples, pears, quinces, peaches and others. Modern strawberry cultivation began in the 18th century in Europe, where two wild strawberry species, *Fragaria virginiana* from North America and *Fragaria chiloensis* from Chile, were hybridized. This hybridization resulted in the large, sweet strawberries we know today. Since then, strawberry cultivation has spread all over the world and has become one of the most important horticultural crops)Al-Khayri and Islam, 2018 .(It contains a wide range of important nutrients, including vitamin C, dietary fiber, antioxidants, and minerals such as potassium, magnesium and iron. These nutrients make strawberries a healthy fruit that helps boost immunity, improve heart health, and reduce the risk of many chronic diseases. In addition, strawberries are used in many food products such as jams, juices, and desserts, increasing their commercial value (Zhao, 2007; Wang et al., 2019)

Fruit plants, including strawberries, are continuously fertilized with various fertilizers to provide essential nutrients and the plant is prepared due to the significance of these elements in the growth and development of plants., but the availability of most of the elements added to the soil may decrease, for various reasons or the loss of a quantity of them by washing, sedimentation and others, this results in significant wastage of fertilizer, leading to the necessity of reducing the loss of nutrients when administered to the soil. One effective method to achieve this is through foliar spraying, a technique that is regarded as highly efficient and rapid. This approach facilitates nutrient absorption, particularly in cases where soil conditions are suboptimal, including instances of elevated or low temperatures, or instances of nutrient loss through washing. Additionally, foliar spraying ensures the uniform distribution of nutrients throughout the plant. (Dang, 2005 ; Lovatt, 2013).

Iron is one of the essential micronutrients required for plant growth and development, which must be in an active form (Fe^{+2}) with a concentration of 100-500 mg kg^{-1} leaf dry weight, and the toxicity of this element begins when its active amount exceeds 500 mg kg^{-1} leaf dry weight, while iron deficiency symptoms appear when its active concentration in leaves is about 50-100 mg kg^{-1} leaf dry weight depending on the type and variety of the plant (Havlin et al., 2005), Iron contributes to several tasks within the plant, Ferredoxin is included in this category and functions as an electron transporter in the process of photosynthesis, as well as Nitrate Reductase and Nitrogen Fixation enzymes. Furthermore, it is a constituent element in the synthesis of other enzymes, including catalase and peroxidase, as well as in the synthesis of leghemoglobin-type proteins that act as an oxygen carrier in fixing atmospheric nitrogen, and iron is included in some important structures in the plant, where it is considered one of the components of nucleus membrane lipids, chloroplasts and mitochondria, and helps in the formation of cell membrane proteins and the process of cell division (Barker and Stratton, 2015; Al-Zhairi et al. 2021),

Also, Zinc is one of the essential micronutrients for the plant, which is absorbed by the plant as Zn^{+2}, and its concentration in plant tissues is 25-150 mg kg^{-1} leaf dry weight. It has several functions within the plant, as it has a role in the formation of a series of essential enzymes, including Carbonic anhydrase, Malic dehydrogenase, Proteinase, Peptidase and other enzymes, as it acts as a pH regulator in the chloroplast and stimulates the work of plant growth regulators and has an important role in building chlorophyll. The substance under consideration is an essential mineral that facilitates normal plant growth and development. It is a component of many enzymes and proteins, and it is also necessary for the synthesis of tryptophan, a precursor to indole acetic acid (IAA) that promotes growth by acting as a growth-promoting substance. (Havlin et al., 2005; Nasiriet et al. 2010 and Yaqoub and Salah El-Din, 2022), Although it does not enter its structure, it enters into the construction of enzymes responsible for the formation of chlorophyll, and also has a major role in nitrogen metabolism in the plant, so its deficiency leads to a sharp decrease in the level of RNA and the content of cells from ribosomes, which causes inhibition of protein formation(Rudani et al., 2018). Research with Saha et al. (2019) showed that foliar spraying with iron and zinc improved vegetative growth, flowering, fruiting and fruit quality parameters of strawberry plants cv. Winter Dawn. Bopparaju et al. (2022) showed that foliar spraying of iron and zinc caused a significant increase in the growth and yield traits of strawberry plants cv. Winter Dawn. The research by Deshwal et al. (2024) on the outcomes of foliar spraying with iron and zinc caused improvement in the quality of strawberry fruits cv. Chandler in western Uttar Pradesh conditions. So, because the availability of Fe and Zn in the soil used in this experiment was very low, the current study was conducted with the objective of ascertaining the optimal concentrations of Fe and Zn for enhancing vegetative and fruit growth, yield, and quality attributes of Fragaria × ananassa cv. Albion cultivated under controlled greenhouse conditions.

MATERIALS AND METHODS

The study was conducted in an unheated playhouse under the jurisdiction of the Department of Horticulture and Landscape Design, which is affiliated with the College of Agriculture and Forestry at the University of Mosul in Nineveh Governorate. The playhouse, measuring 54 meters in length and 9 meters in width, encompasses an area of 486 square meters. m^2 for the period from 15/9/2023 to 1/9/2024 to study the effect of foliar spraying with iron and zinc each alone or in compination on the growth and yield of strawberry plants (*Fragaria* x *ananassa* Duch.). The soil of the polyhouse was plowed with two perpendicular plows, well leveled and divided into three terrace along the length of the polyhouse, where each terrace represents a replicate, and random 4 soil samples were taken, 0-30 cm deep from different places of the terrace and some physical and chemical characteristics were estimated according to the methods mentioned by Page et al.,1982 and Black,1965 (Table,1).

Table (1): Some physical and chemical characteristics of the soil.

Parameter	Value	Unit
Sand	593.7	gm kg^{-1}
Silt	249.6	gm kg^{-1}
Clay	156.7	gm kg^{-1}
Texture	Loamy	.....
EC	0.19	dS m^{-1}
pH	7.05	
Organic matter	12.32	gm kg^{-1}
Available N	6.61	mg kg^{-1}
Available P	2.46	mg kg^{-1}
Available K	13.59	mg kg^{-1}
Available Fe	0.971	mg kg^{-1}
Available Zn	0.280	mg kg^{-1}

* The measurements were conducted in the central laboratory of the College of Agriculture and Forestry, University of Mosul, Iraq.

The experimental was conducted according to Randomised Complete Block Design (RCBD) with two factors (iron and zinc) as foliar spray, four concentrations of iron (0, 10, 20, 30 mg Fe L^{-1}) by utilization Fe-EDDHA(6% Fe) and three concentrations of zinc (0, 150, 200 mg Zn L^{-1}) by using ZnEDTA (12% Zn), with three replicates and eight plants per each experimental unit, thus the number of plants used in the study was 4 × 3 × 3 × 8 = 288 plants.

The strawberry seedlings, cv. Albion, were selected from the nurseries of the College of Agriculture and Forestry/University of Mosul had almost homogeneous growth, and then the wounded roots and large leaves were removed, while keeping two new leaves. Compound fertilizer NPK (20:20:20) at the amount of 5 g $plant^{1}$ were added before planting, on the upper surface of the terrace and mixed it well with the soil, then irrigated it directly, then covered all the terrace with black polyethylene, making holes at the top of the terrace at a distance of 25 cm between one hole and another for planting plants. On 15/9/2023, plants were planted in three lines; the distance between one line and another is 30 cm, and the distance between one plant and another is 30 cm. The plants were sprayed with iron and zinc three times a season (30, 60 and 90 days after transplantation).

Experimental Measurements:

1. **Leaves total chlorophyll (mg g^{-1} fresh weight):** according to the method mentioned by Mackinney/Arnon (Mackinney, 1941 and Arnon 1949) which were described by Saieed (1990).

2. Number of leaves (leaf plant^{-1}): The number of fully developed leaves formed on the plant from the start of the experiment until the end of the experiment was counted, and the number of leaves taken to estimate the chlorophyll of the leaves was added.

3. Leaf area (cm^2 leaf^{-1}): The area of one leaf was estimated according to the method mentioned by Dvornic (1965) by taking 5 full-width leaves from each experimental unit and separating the petioles from them; then, five squares were taken from each leaf with an area of 1 cm^2 each. The leaves and squares were dried by placing them in perforated paper bags in an electric oven at a temperature of 70 °C for 72 hours, then the dry leaves were weighed with the squares as well as the squares alone, and then the average area of the leaves was calculated according to the following equation: -

$$\text{Area of five leaves (cm}^2\text{)} = \frac{\textbf{\textit{Area of the 25 cut squares (cm2)}}\times \textbf{\textit{Dry weight of the five leaves (g)}}}{\textbf{\textit{Dry weight of the 25 cut squares (g)}}}$$

The number of leaf area was found by dividing the area of five leaves by five.

4. Number of runners (runners plant^{-1}): The number of runners of 8 plants at the end of the experiment was calculated, and the average number of runners per plant was found by dividing the total number of runners by eight.

5. Number of fruits (fruit plant^{-1}): The number of fruits was recorded from the first fairy to the last fairy for the eight plants for each experimental unit, then the result was divided by eight to calculate the number of fruits per plant.

6. Fruit weight (g): The weight of one fruit was calculated by dividing the plant yield(g) by the number of fruits formed on one plant and for all fairies.

7. Fruit length and width (mm): The length and width of 5 fruits were measured randomly for each experimental unit in each harvest using Verniar, and the average length and width of one fruit per each harvest was extracted, then the product was extracted by dividing the sum of the length and width of the fruit of all harvests by the number of harvests as in the following two equations:

Average length or width of the fruit per harvest = the sum of the length or width of 5 fruits per harvest / 5.

Average length or width of the final fruit (mm) = the sum of the average length or width of the fruits of all harvests / the number of harvests.

8. Plant yield (g): It was calculated for the eight plants at all harvests for each experimental unit and then divided by eight to extract the single plant yield.

Statistical analysis: The data were statistically analysed utilising the SAS program by the chosen design (SAS, 2000), acomparison of the means was conducted using Duncan's Multiple Range Test at the 5% level.

RESULTS AND Discussion

The data in table (1) showed that the available Fe and Zn (0.971 and 0.280 mg kg^{-1}respectively) is very low as menthiond by Awad and Samir (2008), they indicated that the optimum concentrations of Fe and Zn in the soil was 2.5-4.0 and 0.5-1.0 mg kg^{-1}respectively, this may be attributed to high levels of soil pH (7.05), Havlin et al. (2005) indicated that the soil pH exceed 5, the availability of Fe and Zn may be expected.

Results in Tables (2, 3 and 4) showed that foliar spray with iron at all concentrations (10, 20 and 30 mg L^{-1}) significantly increased all the studied traits (leaves total chlorophyll, number of leaves per plant, leaf area, number of runners and number of fruits per plant, fruit weight, fruit length and width and plant yield) as compared with control, Meanwhile the treatment of 30 mg Fe L^{-1} gave the highest means of all traits which was significantly superior to the other treatmens. These findings are obtained by Mohamed et al. (2022). This may be attributed to the role of iron in leaves chlorophyll as evidence has emerged indicating the involvement of iron as a co-enzyme in the biochemical processes involved in synthesizing chlorophyll. Moreover, the presence of iron as a co-enzyme has been identified in chlorophyll synthesis, as well as in active components of cytochromes. (Al-Aa'reji et al.,2010), In addition, the role of iron as an active factor in the structure of various enzymes, including catalase, peroxidase, oxidase, and cytochrome, has been well-documented. These enzymes play a crucial role in facilitating the activation performance of numerous physiological processes within plant cells (Marschner, 1986). In conclusion, iron plays a pivotal role in the process of chlorophyll synthesis. It facilitates the condensation of glutamate to 5-aminolevulinic acid and the conversion of Mg-protoporphyrin IX methyl ester to protochlorophyllide. These reactions represent the two primary steps in the synthesis of chlorophyll (Mukherji and Ghosh, 2005), the subsequent section will address the speed and products of photosynthesis, which are utilized in various growth processes. Additionally, it will be discussed how these processes increase the amount of growth hormones IAA and GA3 in the leaves. These hormones work to increase cell division and expansion, which causes increased vegetative growth of the plant. As previously mentioned in the works of Jandeh (2003), Sekhon (2014), Tanou et al. (2017), and Al-Asadi and Al-Khaykani (2019). Furthermore, iron plays a pivotal role in the synthesis of numerous non-heme compounds, the most significant of which is ferredoxin, which facilitates the transfer of electrons in a multitude of vital processes within the plant, including photosynthesis. Additionally, iron is implicated in the synthesis of nitrogenous enzymes (Marschner, 1986 and Phogat et al., 2016), and the increase in vegetative growth and its activity in the synthesis of nutrients increases the formation of fruits in terms of number and size. (Kamiab and Zamanibahramabadi, 2016).

Table (2): Effect of foliar spray with iron, zinc and their interaction on leaves' total chlorophyll (mg g^{-1}), Number of leaves (leaf $plant^{-1}$) and leaf area(cm^2) of strawberry plants cv. Albion.*

Zn Conc. (mg L^{-1})	Fe Conc. (mg L^{-1})				
	0	10	20	30	Means (Zn)
	Leaves total chlorophyll (mg g^{-1} fresh weight)				
0	21.56j	28.99h	31.07g	33.73f	28.84a
150	27.83i	33.99ef	34.69de	35.50cd	33.00b
200	27.97i	36.25c	40.16b	43.24a	36.91a
Means (Fe)	25.79d	33.07c	35.31b	37.49a	
Number of leaves (leaf $plant^{-1}$)					
0	25.01k	29.74h	32.74g	34.40f	30.47c
150	26.79j	34.90f	35.95e	36.59d	33.56b
200	27.67i	37.54c	38.68b	39.81a	35.93a
Means (Fe)	26.49d	34.06	35.79b	36.93a	

leaf area (cm^2)					
0	78.00k	93.69h	100.82g	106.51f	94.75c
150	84.09j	110.32e	111.53de	113.13d	104.77b
200	86.82i	116.74c	122.50b	126.47a	113.13a
Means (Fe)	82.97d	106.91c	111.62b	115.37a	

* The means of iron and zinc each alone or togather for each parameter that share the same letters are not significantly different according to Duncan's multiple range test at 0.05.

Table (3): Effect of foliar spray with iron, zinc and their interaction on the number of runners (runner $plant^{-1}$), Number of fruits (fruit $plant^{-1}$) and Fruit weight (g) of strawberry plants cv.Albion.*

Zn Conc. ($mg\ L^{-1}$)	Fe Conc. ($mg\ L^{-1}$)				
	0	10	20	30	Means (Zn)
	Number of Runners (runners $plant^{-1}$)				
0	8.36l	13.79i	14.18h	14.71g	12.76c
150	11.81k	15.24f	15.57e	16.48d	14.77b
200	12.76j	17.21c	17.79b	18.51a	16.57a
Means (Fe)	10.97d	15.41c	15.85b	16.56a	
Number of fruits (fruit $plant^{-1}$)					
0	15.16i	15.86hi	16.28h	22.66e	17.49c
150	17.68g	22.98e	23.60e	24.58d	22.21b
200	20.33f	26.18c	28.30b	30.90a	26.43a
Means (Fe)	17.72d	21.67c	22.73b	26.05a	
Fruit weight (g)					
0	11.59i	13.81h	15.14g	16.68de	14.31c
150	15.64f	16.87d	17.05d	17.72c	16.82b
200	16.29e	17.99c	18.53b	19.56a	18.09a
Means (Fe)	14.51d	16.22c	16.91b	17.99a	

* The means of iron and zinc each alone or togather for each parameter that share the same letters are not significantly different according to Duncan's multiple range test at 0.05.

Table (4): Effect of foliar spray with iron, zinc, and their interaction on Fruit length (mm), Fruit width (mm) and Plant yield (g) of strawberry plants cv.Albion.*

Zn Conc. (mg L^{-1})	Fe Conc. (mg L^{-1})				
	0	10	20	30	Means (Zn)
Fruit length (mm)					
0	26.05k	29.29j	32.47i	40.06fg	31.97c
150	36.08h	40.72f	41.90e	43.07d	40.44b
200	39.55g	46.54c	52.89b	57.08a	49.01a
Means (Fe)	33.89d	38.85c	42.42b	46.74a	
Fruit width (mm)					
0	13.70j	19.54i	23.51h	29.31f	21.51c
150	27.12g	29.51ef	30.41de	31.36cd	29.60b
200	29.07f	32.27c	35.4b1	38.39a	33.78a
Means (Fe)	23.29d	27.11c	29.77b	33.02a	
Total yield (g $plant^{-1}$)					
0	175.8k	219.1j	246.6i	378.0f	254.9c
150	276.5h	387.6ef	402.4e	435.6d	375.5b
200	331.4g	470.9c	524.7b	605.1a	483.0a
Means (Fe)	261.2d	359.2c	391.2b	472.9a	

* The means of iron and zinc, each alone or together, for each parameter that share the same letters are not significantly different according to Duncan's multiple range test at 0.05.

The results of the same tables (2,3 and 4) indicate that foliar spray with zinc at both concentrations (150 and 200 mg L^{-1}) led to a significant increase in all studied traits compared to the control treatment, while foliar spray of zinc at 200 mg L^{-1} significantly superior and gave the highest values of all traits (leaves total chlorophyll, number of leaves per plant, leaf area, number of runners and fruits per plant, fruit weight, length and width of the fruit and plant yield). These results are consistent with what Abdollahi et al. (2010), Al-Esaily (2011), Lolaei et al. (2012), Deepika et al. (2024) and Ullah et al. (2023) reported when foliar spraying strawberry plants with zinc. The significant increase in all the above parameters with zinc spray may be attributed to the role of zinc in activating of some enzymes and increasing the level of endogenous auxins, which may positively affected cell division and elongation through Zn role in the synthesis of the amino acid tryptophan as a biosynthesis of auxin IAA(Al-Sahaf,1989 and Chaturvedi et al., 2005), and the significant effect of zinc on vegetative growth may be due to its physiological role in activating and building IAA and preventing its oxidation, which plays a stimulating role in the growth and elongation of plant cells (Anonymous, 2014), in addition to the fact that zinc is a co-factor of many important enzymes in biological processes, especially photosynthesis, conversion of sugars to starch and synthesis of proteins (Mengel and Kirkby, 2001).

It is also noted from the results of tables (2,3 and 4) that the double interaction between iron and zinc had a significant effect on all the studied traits, as the interaction between 30 mg Fe L^{-1} and 200 mg Zn

L^{-1} gave the highest means of leaves total chlorophyll, number of leaves per plant, leaf area, number of runners and fruits per plant, fruit weight, length and width of the fruit and plant yield. Kazemi (2014), Saha et al. (2019), and Mahmood and Al-Dulaimy (2021) indicated that foliar spray with iron and zinc, each alone or together, significantly increased the growth and yield of strawberry plants. These results may be due to an accumulation effect of iron and zinc that used in this study, which led to increasing the leaf chlorophyll content and their effect on the probable increase of photosynthesis and its protects, which may be using a part of this protects in improving plant growth and fruiting; Mahmood and Al-Dulaimy (2021).

CONCLUSION

Albion strawberry plant cv. grown in loamy soil at unheated polyhouse at a distance of 30*30 cm sprayed with four concentrations of iron (0, 10, 20, 30 mg Fe L^{-1}) by using Fe-EDDHA(6% Fe) and three concentrations of zinc (0, 150, 200 mg Zn L^{-1}) by using ZnEDTA (12% Zn). The results exhibited that different concentrations of iron and zinc have enhanced growth, yield and quality of the fruits of Albion strawberry plants as compared with control. The results also exhibited that the combined application of 30 mg Fe L^{-1} + 200 mg Zn L^{-1} yielded the highest means of all studied parameters as it significantly increased vegetative growth, plants yields and improved fruit quality of strawberry plant cv. Albion.

REFERENCES

Abdollahi, M.; S. Eshghi and E. Tafazoli1(2010). Interaction of Paclobutrazol, Boron and Zinc on Vegetative Growth, Yield and FruitQuality of Strawberry (*Fragaria* × *Ananassa* Duch. Cv. Selva). J.BioL. ENVIRON.SCI.4(11):67-75.

Al-Aa'reji, J. M.; M. S. Duhoky and A. A. T. Mayi (2010). Effect of foliar spray with iron and GA_3 on yield and quality of apple fruits cv. Starking Delicious. Meso. J. Agric. 38(3): 4-11.

Al-Asadi, M. H. S. and A. H. J. Al-Khaykani (2019). Plant hormones and their physiological effects. Dar Al Warith for Printing and Publishing. Faculty of Agriculture, Al-Qasim Al-Khadra University.

Al-Esaily, I. A. S. (2011). EFFECT OF FOLIAR SPRAY WITH ZINC AND BORON ON GROWTH, YIELD AND FRUIT QUALITY OF STRAWBERRY*(Fragaria × ananassa Duch cv. Camarosa)* PLANTS GROWN IN SANDY SOIL. *J. Product. & Dev., 16(3):483 – 506.*

Al-Khayri, J. M., & Islam, R. (2018). Genetic Improvement of Strawberry (Fragaria× ananassa Duchesne). In *Advances in plant breeding strategies: Fruits* (pp. 217-275). Springer, Cham.

Al-Sahhaf, F. H. (1989). Applied plant nutrition. House of Wisdom for Printing and Publishing. University of Baghdad. Republic of Iraq. In Arabic.

Al-Zhairi, F. F. ; Al-Aareji, J. M. A. and . Al-Taae, A. K. (2021) . Effect of rootstock and bio-fertilizers on some mineral concentrations in the leaves of Local Lemon (Citrus limon L.) transplants and available nutrients in the Media. IOP Conf. Series: Earth and Environmental Science 735. doi:10.1088/1755-1315/735/1/012045.

Anonymous (2014): Haifa. Strawberry crop guide: mineral nutrition of strawberries. – http://www.haifagroup.com/knowledge_center/crop_guides/strawberry/mineral_nutrition_of_strawberries/.

Arnon, D. I. (1949). Copper enzymes in isolated chloroplasts. Polyphenoloxidase in Beta vulgaris. *Plant physiology*, *24*(1), 1.

Awda, Mahmoud and Samir, Shamsham(2008). Soil Fertility and Plant Nutrition. Al-Baath University Publications.Syria.

Barker, A.V. and M.L. Stratton (2015). Iron. Chapter 11. In: Barker, A.V. and Pilbeam, D.J. (eds): Handbook of Plant Nutrition. 2^{ed} ed. CRC Press.Taylor and Francis Group. London. New York, pp: 399-426.

Black, C. A. (1965). Method of Soil Analysis. Part (2). Amer. Soc. Agron. Inc. USA.

Bopparaju, A. K., D. S. Mishra, and V. Bahadur (2022). Effect of Foliar Application of Iron (Fe) and Zinc (Zn) on Growth, Yield and Quality of Strawberry (Fragaria ananassa) Cv. Winter Dawn. International Journal of Plant & Soil Science. 34(23): 587-593. DOI: 10.9734/IJPSS/2022/v34i232464.

Chaturvedi, O. P.; A. K. Singh; V. K. Tripathi & A. K. Dixit (2005). Effect of Zinc and Iron on Growth, Yield and Quality of Strawberry cv. Chandler. Acta Hort 969: 237 – 240.

Dang, S., L. Cheng; C.F. Scagel and F. Fuchigami (2005). Timing of urea application affects leaf and root N uptake in young Fuji\M9 apple trees. J. Horti. Sci. Biotech., 80:116-120.

Deepika, V. Mishra, S. Bahadur, V. and Kushwaha, A. (2024). Effect of Tricho capsules and different micronutrients on growth, yield and quality of Strawberry (Fragaria x ananassa Duch.) cv. Chandler. Journal of Advanced Biochemistry Research, 8 (5): 1008-1011.

Deshwal, A.; J. Singh; A. Tiwari; S. Kumer Singh; A. Vikram Singh and M. S. Rathi (2024). Effect of micronutrients on fruit quality of Strawberry (Fragaria × ananassa Duch.) cv. Chandler in western Uttar Pradesh conditions. International J. of Agri. Invention 9(1): 105-109. DOI:10.46492/IJAI/2024.9.1.16.

Dvorinic, V. (1965). Lacarali pactic de amelo graphic, Ed. *Dielactict Spedagogica. Bucureseti. RS Romania*.

Havlin, J. L.; J. D. Beaton; S. L. Tisdale and W. L. Nelson (2005). Soil Fertility and Fertilizer. 7^{th} ed. Upper Saddle River, New Jersey 07458.

Jundia, H. (2003). Physiology of fruit trees. Arab House for Publishing and Distribution, Nasr City, Arab Republic of Egypt. In Arabic

Kamiab, F. and E. Zamanibahramabadi . (2016). The effect of foliar application of nano-chelate super plus ZFM on fruit set and some quantitative and qualitative traits of almond commercial cultivars. J. Nuts, 7(1): 9-20. DOI:10.22034/JON.2016.522950

Kazemi,M.(2014). INFLUENCE OF FOLIAR APPLICATION OF IRON, CALCIUM AND ZINC SULFATE ON VEGETATIVE GROWTH AND REPRODUCTIVE CHARACTERISTICS OF STRAWBERRY CV. 'PAJARO. ' Trakia Journal of Sciences, 12 (1):21-26.

Lolaei, A.; M. A. Rezaei ; M. K. Raad and B. Kaviani 2012). Effect of Paclobutrazol and Sulfate Zinc on Vegetative Growth, Yield and Fruit Quality of Strawberry (*Fragaria × ananassa* Duch. cv. Camarosa). Annals of Biol. Res. , 3 (10):4657-4662.

Lovatt, C.J.(2013). Properly timing foliar-applied fertilizers increases efficacy: A review and update on timing foliar nutrient applications to citrus and avocado. HortTechnol., 23(5):536–541.

Mackinney, G. (1941). Absorption of light by chlorophyll solutions. *Journal of biological chemistry*, *140*(2), 315-322.

Mahmood, M. M. and A. F. Al-Dulaimy (2021).Response of Strawberry CV. Festival to Culture Media and Foliar Application of Nano and Normal Micronutrients. IOP Conf. Series: Earth and Environmental Science 904 (2021) 012067 doi:10.1088/1755-1315/904/1/012067.

Marschner, H. (1986). "Mineral Nutrition of Higher Plants," 2nd Edition, Academic, London, 1995, pp. 369-379.

Mengel, K. & E. A. Kirkby (2001) Principles of Plant Nutrition, 5th edition 15BN 0-7973-7150-x.

Mohamed, A.O.A; B. K. Mohammed and S. M. Taha (2022). Effect of humic acid and chelated iron on yield and quality of two strawberry cultivars (*Fragaria* X *ananassa* Duch.) Euphrates J. of Agric. Sci.,12 (2):405-422.

Mukherji, S. and A. K. Ghosh (2005). Plant Physiology. New Central Book Agency *(p)* Ltd. 8/1 Chintamoni Das Land, Kolkata/India.

Nasiri, Y.; S. Zehtab-Salmasi,; S. Nasrullahzadeh,; N. Najafi, and K. Ghassemi-Golezani, (2010). Effects of foliar application of micronutrients (Fe and Zn) on flower yield and essential oil of chamomile (Matricariachamomilla L.). Journal of Medicinal Plants Research, 4:1733- 1737.

Page, A. L., Miller, R. H., & Keeny, D. R. (1982). Methods of Soil analysis part (2) 2nd (ed). Agronomy 9. *Amer. Soc. Agron. Madison Wisconsin. Papanicolaou, EP (1976). Determination of cation. Exchange capacity of calcareous soils and their percent base saturation. Soil Sci*, *121*, 67-71.

Phogat, N., S.A. Khan; S. Schankar; A. A. Ansary and I. Uddin (2016). Fate of inorganic nanoparticles in agriculture. Adv Mater Lett, 7: 3-12. doi.org/10.5185/amlett.2016.6048

Rudani, K. , V. Patel and K. Prajapati (2018). THE IMPORTANCE OF ZINC IN PLANT GROWTH – A REVIEW. International Research Journal of Natural and Applied Sciences5(2):38-48. http://www.aarf.asia/

Saha, T., Ghosh, B., Debnath, S. and Bhattacharjee, A. (2019). Effect of micronutrients on growth, yield and quality of strawberry (Fragaria × ananassa Duch.) cv. Winter Dawn in the Gangetic Alluvial Region of West Bengal, Journal of Crop and Weed, 15(1): 92-95.

Saieed, N. T. (1990). *Studies of variation in primary productivity morphology about elective improvement of broad-leaved tree species* (Doctoral dissertation, PhD Dissertation. Naational University of Ireland).

SAS, Institute, Inc. (2001). The SAS system for Windows. Release 8.02. SAS inst., Inch., Cary, N.C.

Sekhon, B. S.(2014).Nanotechnology in agri-food production: an overview.Nanotechnology, Science & Appli., 7: 31-53. doi: 10.2147/NSA.S39406

Tanou, G. , I.S.Minas ; F. Scossa;M. Belghazi; A. Xanthopoulou and I. Ganopoulos (2017). Exploring priming responses involved in peach fruit acclimation to cold stress. Sci. Rep., 7:11358. DOI:10.1038/s41598-017-11933-3

Ullah, A., Sajid, M., Zakirullah, H., Alamgir Khan, Z. J., & Shah, Z. (2023). 48. Effect on yield and qualitative characteristics of strawberry (Frageria x annanasa) cv. Chandler to foliar application of gibberellic acid and zinc. Pure and Applied Biology (PAB), 12(1), 555-559.

Wang, W.; Wang, S.; Wang, M.(2019). Status and extension experience protected strawberry cultivation technology in Daxing district. J. Veg., 4, 67–70.

Yaqoub, Mohammed Mohammed and Salahuddin Mustafa Abu Gharsa (2022). Fundamentals of Plant Nutrition (A translated book by Konrad Mengel and Ernest A. Kirkby). Publications of Omar Al-Mukhtar University, National Library, Benghazi, Libya.

Zhao, X. Q., Mitani, N., Yamaji, N., Shen, R. F., & Ma, J. F. (2010). Involvement of silicon influx transporter OsNIP2; 1 in selenite uptake in rice. *Plant Physiology*, *153*(4), 1871-