ISSN: 2458-8989

Natural and Engineering Sciences

NESciences, 2025, 10 (3): 755-765 doi: 10.28978/nesciences.1811157

# The Effect of Spraying with Iron and Manganese Saturated with Salicylic Acid on the Storability of Shilik Fruits

Athraa Khairi Abd Oun [1*]

[1*] Presidency of University of Baghdad, Iraq. E-mail: athraa.k@uobaghdad.edu.iq

## Abstract

Objective: This study investigates the effect of foliar spraying with iron and manganese saturated with salicylic acid on the storability and yield of Shalik (strawberry) fruits. Methods: The experiment was conducted in a greenhouse during the 2022-2023 growing season. Research utilized an RCBD with a factorial layout involving four levels: two types of metal at ten different concentrations each—iron ranging from 100 to 0 mg/L in increments—and another type of element also varying across eight distinct quantities—from 20 to 0 mg/L. Three replicates of treatment were conducted using 5 seedlings in each experimental setting. The data was examined through the use of SAS software, and comparisons between mean values were conducted via Duncan's Multiple Range Test at an alpha level set at. The 05th probability threshold is being referred to here. Outcome: An elevation by 18% was observed when applying an iron concentration of 100 milligrams per liter. The measurement is 78 centimeters, along with its corresponding weight of 312 grams. The value 10 is represented by this symbol: A particularly high level of 20 milligrams per liter of manganese combined with salicylic acid enhanced crop yields dramatically; there was also an observable boost in the quantity of individual plants bearing more than six fruits each. And the quantity of fruits is 21 units. The volume is 0. 016 cubic centimeters. The interaction of iron and manganese applications led to the maximum yield at 72%. Eight grams of substance yield on each individual plant; specifically, one gram is produced for every eight units consumed by the organism. The yield is 44 metric tonnes per hectare. Conclusion: The study concluded that foliar spraying with 100 mg/L of iron and 20 mg/L of manganese saturated with salicylic acid significantly enhances the growth, yield, and storability of Shalik fruits. These results suggest that optimized nutrient applications can improve fruit quality and agricultural productivity.

## Keywords:

*Iron, manganese, salicylic acid, shalik fruits, foliar fertilization, fruit yield, agricultural productivity.*

## Article history:

Received: 15/07/2025, Revised: 02/09/2025, Accepted: 03/10/2025, Available online: 12/12/2025

**Corresponding Author: Athraa Khairi Abd Oun, E-mail: athraa.k@uobaghdad.edu.iq*

## Introduction

The Shalik plant (strawberry, Fragaria ananassa) belongs to the Rosaceae family and is one of the most important crops globally (Shah et al., 2022; Al-Abidy & Al-Janabi, 2024). Known for its small fruits, the Shalik plant is widely cultivated due to its large number of varieties and its ability to adapt to diverse environmental conditions. Its relatively short vegetative growth, with a maximum height of 25-30 cm, allows it to thrive in various climates. The fruit is rich in essential nutrients such as proteins, fats, carbohydrates, magnesium, calcium, zinc, phosphorus, copper, and potassium, as well as vitamins C, riboflavin, and thiamine (Ssemugenze et al., 2025; Masina Sairam et al., 2024). Shalik fruits are widely used in the food industry for products like ice cream, jams, and pastries, and they also possess medicinal and therapeutic properties, including antibacterial effects and disease treatment capabilities (Whitmore & Fontaine, 2024).

Foliar fertilization is a key agricultural practice used to address nutrient deficiencies and enhance the availability of nutrients within the soil (Geetha, 2024; Sudhandiradevi & Sabin Begum, 2025; Àlvarez-Fernàndez et al., 2006). Among the critical micronutrients required for plant growth are iron and manganese. Iron, absorbed in its binary form (Fe++), plays a vital role in chlorophyll formation, photosynthesis, and enzyme synthesis. It is crucial in the process of converting nitrogen in leaves into proteins and protects chlorophyll from degradation due to sunlight, thus preventing leaf yellowing in certain plants (Niu et al., 2021; Januszkiewicz et al., 2023). Furthermore, iron supports the formation of cytochromes and ferredoxin compounds, which are essential for the photosynthetic process (Hemasree et al., 2025). This contributes to enhanced growth rates by increasing the plant's leaf area, thus supporting overall plant health and productivity (Veerasamy & Fredrik, 2023).

Manganese, when saturated with salicylic acid, also plays a significant role in plant growth and development (Shahsavar et al., 2024; Shamili et al., 2021). It is involved in the process of respiration, nitrogen metabolism, and enzyme activation, which are crucial for photosynthesis and the formation of chlorophyll (Ray et al., 2025). Additionally, manganese enhances the plant’s ability to resist pests and diseases. Salicylic acid, a plant hormone, has gained attention for its physiological roles, particularly in regulating ion absorption, hormonal balance, and stomatal movement, all of which are vital for overall plant health.

Previous studies have shown that the interaction of iron and other nutrients, such as zinc, leads to significant improvements in growth and yield characteristics. For example, spraying plants with chelated iron (50 mg/L) and salicylic acid (100 mg/L) has been shown to enhance the fruit's weight and size, while a combination of lower concentrations of these nutrients has been found to improve chemical characteristics like the percentage of dissolved solids and sugars.

### *Key Contributions*

- This study investigates the synergistic effects of foliar spraying with iron and manganese saturated with salicylic acid on the yield and quality of Shalik fruits.
- The research determines the optimal concentrations of these treatments to maximize fruit size, weight, and storage capacity, providing valuable insights for improving Shalik plant productivity.
- The study contributes to the understanding of how foliar fertilization with specific micronutrients and plant hormones can enhance crop performance under varying environmental conditions.

Paper Organization: The paper is organized in the following way: Introduction: The paper will give some background information on the Shalik plant nutrition and the effect of iron, manganese and salicylic acid in plant growth. It also presents the major objectives of the study. Materials and Methods: refers to the

design of the experiment, including the treatments, methods of data collection and statistical analysis. Results and Discussion: This section contains the results of the study, along with the discussion of the impacts of various treatments on the Shalik fruit traits. Conclusion: Overviews the findings based on the results, referring to the practical implications of the obtained findings and provides the directions to the further research.

## Materials and Research Methods

### *Study Site and Experimental Conditions*

The site of the study and experimental conditions were as follows. The experiment has been done in a controlled greenhouse within the growing season of 2022 to 2023 in Baghdad, Iraq. The natural daylight and the standard horticultural environment offered by the green house was favorable to cultivate Shalik (Fragaria ananassa). The temperature, humidity and ventilation were kept constant throughout the study period to reduce the effects of environment in terms of variation during the growth and fruit development of plants.

### *Planting Material and Soil Preparation*

Healthy and homogeneous Shalik seedlings were stored in refrigerated stores in Baghdad and ready to be transplanted. The soil in the green house before planting was plowed, softened and leveled. Thirty centimeters of soil were gathered without any sample removal for analysis within a lab setting to determine both its physical and chemical characteristics. The soil had characteristics typical of sandy loam: it contained approximately 70% sand by weight, about 24% silt, and only 5% clay; moreover, this particular sample exhibited an optimal pH level at 7. Moreover, it exhibits an electrically conductive property at a rate of 1. The quantity 0. 027 joules per second-kilogram is represented as 53 D S^-1. The concentration of macronutrients was 8 mg/L for calcium. A concentration of 0. 25 mmol/L along with magnesium at an amount of 6 is measured in this context. Concentration of 96 millimoles per liter is represented by -, while sodium concentration stands at 5 units. Concentration of 30 millimoles per liter is indicated by -, while potassium concentration stands at 0 mEq/L. A concentration of 20 millimoles per liter is being referred to here. Transplanting the saplings took place on November 15th in 2022; seeds were spaced out by 40 centimeters apart within each row, as well as among individual plants.

### *Experimental Design and Treatment Structure*

The experiment was designed in terms of a factorial layout with Randomized Complete Block Design (RCBD) made of three iron (0, 50, and 100 mg L -1) and three manganese saturated with salicylic acid concentrations (0, 10, and 20 mg L -1). Every treatment combination was repeated thrice and each replicate had five plants and therefore had 45 plants and the study had a total number of 135 plants.

### *Agronomic Management Practices*

All treatments had the same practice of crop management during the experiment period which included irrigation, weeding, and fertilization according to the recommended agronomic practices. Topsin fungicide was used to fight the fungus by applying the fungicide at a concentration of 1.5 g L -1 after a period of two weeks of transplanting. Irrigation was applied when required to ensure sufficient soil moisture and no other nutrient spray was administered to the soils besides the test treatments so that confounding effects could be avoided (Boghori & Tabatabai, 2017).

***Preparation and Application of Foliar Treatments***

The spraying with iron and manganese saturated with salicylic acid on the foliage was conducted twice during the growing season, on 17 December 2022 and 17 February 2023. The 1% liquid soap solution was put into each spray to increase the leaf coverage and decrease the surface tension. Spraying was done in the early morning to avoid quick evaporation and also manganese treatment sprayed before the sun set in the same day. Sprays were sprayed all over until full canopy coverage was achieved.

***Data Collection and Measurements***

In early April of this year, specifically on the 17th day, observations revealed five distinct plant specimens per individual test group. In order to ascertain how many fruits each plant bears, individuals counted the quantity of fruits in every successive harvest over six cycles; these counts were then averaged together to find out an estimated total for fruits per plant on average. A measurement for the quantity of the fruit involved measuring it within a graduated cylinder via the method of water displacement; subsequently, its mass was computed as an average based on weighing each individual piece against known weights representing their respective units. The total fruit weights collected from every fifth plant within an individual area were added up to determine yields for those specific plants individually; these figures then underwent conversion based on proportionality to calculate yields across entire hectares.

This study was conducted inside the greenhouse during the growing season 2022-2023. Shallik (strawberry) seedlings were brought in. From Baghdad, where it was stored in refrigerated warehouses to be ready for planting and of a homogeneous size. After preparing and softening the soil and preparing it for planting, soil samples were taken for analysis and to know the physical and chemical properties as in Table (1).

Table 1. Physical and chemical properties of soil intended for agriculture

| **P.H** | **Histology** | **Clay gm.kg-1** | **Alluvial gm.kg-1** | **Sand is a cloud. kg-1** | **Type of analysis** |
|---|---|---|---|---|---|
| 7.27 | Sandy loam | 62 | 238 | 703 | The Analysis' Results |
| Na mmol. L-1 | Ca mmol l-1 | Mgmmol liter-1 | K mmol l-1 | Ec Ds.m-1 | Type of analysis |
| 5.3 | 8.25 | 6.96 | 0.2 | 1.53 | The Analysis' Results |

The seedlings were planted in the form of lines, the distance between one line and another was 40 cm, and the distance between one seedling and another was 40 cm, on November 15, 2022, and the crop service and recommended agricultural operations were carried out during the trial period, including weeding, watering, fertilizing, and using the fungicide Topsin (top sn) at a rate of (1.5 g.l-1) lu of irrigation water two weeks after transplantation. The experimental parameters included studying the effect of spraying with iron at three concentrations (100, 50, 0) mg. L-1 and manganese saturated with salicylic acid at three concentrations (20, 10, 0) mg. 1 litre, with three replicates, five seedlings per experimental unit, where the number of seedlings for one replicate is 45 seedlings, and the total number of seedlings for the experiment is 135 seedlings. The seedlings were sprayed twice during the growing season on 12/17/2022 and 2/17/2023. Liquid soap, which is a dispersing substance, was used when spraying at a concentration of 1% to obtain a low surface tension of water when spraying on the leaves. The spraying was done with manganese saturated with salicylic acid in Early morning and during the same day before sunset, the treatment was carried out with calcium. The experimental data were analyzed statistically and according to the analysis of variance

table (ANOVA table) using the (SAS 2001) system, and the means were compared using Duncan's multiple range test under the probability level of 0.05, according to what was mentioned by.

Characteristics studied: Measurements were taken at the end of the experiment on 17/4/2023, five plants per experimental unit.

***Attributes of the outcome***

Number of fruits per plant - 1: Readings were taken when harvesting fruits until the last harvest, which is the sixth, for the five plants from each experimental unit. The average number of fruits per plant was calculated as follows:

Average number of fruits per plant -1= Total number of fruits of the five plants/5 plants per experimental unit

Fruit volume (cm3): The volume of the fruit was calculated using the known method of water displaced from a glass graduated cylinder.

Fruit weight (g): The total weight of the fruits in the experimental unit was calculated and then divided by the total number of fruits according to the following equation:

Fruit weight = total weight of fruits per experimental unit / total number of fruits per experimental unit

Per-plant yield (g): Finding the plant yield by dividing the sum of the yield of the five known plants for each experimental unit by five.

Yield per unit area (ton/ha): The yield was calculated for each experimental unit, and the yield per hectare was calculated using the ratio and proportion method.

## Results and Discussion

Table 2. ANOVA summary for yield and fruit characteristics

| Source of Variation | df | Fruit Number (p-value) | Fruit Size (p-value) | Fruit Weight (p-value) | Yield/Plant (p-value) | Yield/ha (p-value) |
|---|---|---|---|---|---|---|
| Blocks | 2 | 0.412 (>0.05) | 0.365 (>0.05) | 0.298 (>0.05) | 0.447 (>0.05) | 0.389 (>0.05) |
| Iron (Fe) | 2 | 0.287 (>0.05) | 0.014 (<0.05) | 0.021 (<0.05) | 0.331 (>0.05) | 0.264 (>0.05) |
| Mn + SA | 2 | 0.008 (<0.05) | 0.011 (<0.05) | 0.198 (>0.05) | 0.009 (<0.05) | 0.010 (<0.05) |
| Fe × Mn+SA | 4 | 0.003 (<0.05) | 0.004 (<0.05) | 0.017 (<0.05) | 0.006 (<0.05) | 0.005 (<0.05) |
| Error | 16 | — | — | — | — | — |
| Total | 26 | — | — | — | — | |

Table (2) ANOVA results indicated that the effect of iron on fruit size and fruit weight was statistically significant because the p-values were found to be less than 0.05 but the effect of iron on fruit number, yield per plant, and yield per hectare was not statistically significant ($p > 0.05$). Salicylic acid-saturated manganese also had significant effect on fruit number, fruit size, plant yield, and hectare yield ($p < 0.05$), which proved the potent physiological effect of salicylic acid on the fruit formation and yield. The combination of iron and manganese saturated with salicylic acid gave the strongest effects on all the traits measured and as such a combination of the nutrient applies greater synergy than does single treatments.

***Effect of Iron on Fruit Growth and Yield***

Application of iron enhanced some quality parameters of fruits especially in relation to fruit size and weight of fruit. The maximum level of iron amount of 100 mg L (minus) produced the maximum fruit size (18.78 cm 3) and maximum weight of fruit (12.10 g). Such improvements are explained by the fact that iron is necessary to synthesize chlorophyll, electron transport, and metabolic activation, all of which contribute to the fact that the developing fruits can accumulate carbohydrates in greater amounts. Nevertheless, the use of iron did not affect the number of fruits per plant and overall yield significantly, indicating that iron is only effective as an enhancer of the quality of fruits but not production.

***Effect of Manganese Saturated with Salicylic Acid***

The salicylic acid impregnated manganese showed a significant positive impact on the fruit count, fruit volume, and yield in general. Optimal concentrations were considered to be 20mg L -1, which gave the following results; 6.50 fruits per plant, 21.16 cm 3 fruit volume, 72.77 g yield per plant and 1.44 ton per hectare yield. All these outcomes indicate the significance of manganese in increased activation of photosynthetic enzymes, better respiration and movement of nutrients inside the plant. Salicylic acid also improves the physiological performance through balancing hormones, boosting antioxidant, and enhancing stress response. When combined, these are associated with better flowering, higher fruit setting and fall under better productivity.

***Interaction Effects Between Iron and Mn+SA***

The combination of iron and manganese that was saturated with salicylic acid also gave the greatest total benefits to all the fruit properties. The mixture of 100 mg L -1 iron + 20 mg L -1 manganese with salicylic acid obtained:

- 6.32 fruits per plant
- 23.50 $cm^3$ fruit volume
- 11.37 g fruit weight
- 72.08 g yield per plant
- 1.43 ton per hectare yield

The result of this action shows clearly that iron and manganese have synergy in their action when used together, which has stronger physiological effects as compared to their individual use. Iron increases photosynthesis, manganese activates important enzymes and salicylic acid increases resistance to stress and efficiency of metabolism (Akrami et al., 2024). The combination leads to improved assimilate partitioning, fruit development and increase in productivity.

***The effect of spraying with iron and manganese saturated with salicylic acid on some yield characteristics of shlek seedlings***

Table 3 revealed that among the examined yield traits like average fruit count, plants' total production, and units' overall output, none exhibited notable disparities between treatments using iron versus control levels; however, higher concentrations outperformed them significantly. A dosage equivalent to 100 milligrams per liter of l-iron led to notable enhancements in characteristic traits such as average fruit size and weight compared to control groups, exhibiting an increment ratio of approximately seventeen percent more than baseline measurements. Forty-four twenty-eight. Fifty-one percent each time. Another study found that this particular concentration - exceeding 20 milligrams per liter - significantly impacted various characteristics when combined with salicylic acid. The count of fruit-bearing plants increased to six units. To compare it with the control group's result of

four points, there was an increase by fifty units. The figure stands at forty-three, experiencing growth at a pace of four-six percent. Sixty-one percent. The mean size of fruits was recorded at 21 units. To 16 cubic centimeters, it was equivalent to an intervention of 12 units in this study. A volume of ninety-five cubic centimeters has seen its growth at a pace of forty-six percent over time. Sixty-one percent. Thirty-three. Thirty-three percent of results were achieved, along with an average crop production rate for each individual plant as well as across entire fields reaching seventy-two units per hectare. Approximately seventy-seven grams; one unit is unspecified. Forty-four units. One hectare is priced at 56 units per unit area. Seventy-seven and fifty-five. The percentage increase was 90% in comparison to the untreated group; however, there were no significant differences observed regarding the mean fruit weights after being exposed to manganese combined with salicylic acid.

Regarding the relationship between iron and manganese levels dissolved in salicylic acid, data revealed an enhancement across various tested traits when these elements were increased through treatments at 100 mg concentration; this effect surpassed other lower doses. In the study, an amount equivalent to 375 ppm of lindane combined with 4 grams per liter of manganous ions dissolved in salicylate solution served as the control substance; here, there were six fruit-bearing plants observed for their yield performance. There were thirty-two instances recorded, averaging at three dozen fruits per instance. A volume of 50 cubic centimeters was achieved; both individual crop yields and per-unit-area yields were recorded at an impressive level of 72 units each. Eight grams and one unit. Forty-four units. In terms of area measurement, 1 hectare was contrasted against another intervention known as the control group, whose size equaled 45 square meters. Eighteen grammes and zero. Eighty-nine units. One hectare in particular.

Table 3. The effect of spraying with iron and manganese saturated with salicylic acid on some yield characteristics of shlek seedlings

| **Studied attributes** | | | | | | **Calcium (mg. l-1)** |
|---|---|---|---|---|---|---|
| Yield per unit area (tons. ha-1) | Yield per plant (g) | Fruit weight (g) | Fruit size (cm3) | Number of fruits. Plant-1 | Manganese (mg. L-1) | |
| 0.89 de | 54.18 de | 9.67 BC | 11.69 f | 4.65 BC | 0 | **0** |
| 1.00 CDE | 550.44 CDE | 10.13 BC | 12.85 EF | 4.98 BC | 10 | |
| 1.53 a | 72.68 a | 11.10 ABC | 19.30 BC | 6.54 a | 20 | |
| 0.84e | 42.37 e | 9.35 c | 11.15 f | 6.65 BC | 0 | **50** |
| 1.21 b | 61.14 b | 12.07 a | 14.63 de | 5.10 b | 10 | |
| 1.46 a | 73.56 a | 11.07 ABC | 20.68 b | 6.65 a | 20 | |
| 1.02 cd | 51.67 cd | 12.88 a | 16.02 d | 3.98 c | 0 | **100** |
| 1.14 BC | 57.56 BC | 12.04 a | 16.84 cd | 4.76 BC | 10 | |
| 1.43 a | 72.08 a | 11.37 ab | 23.50 a | 6.32 a | 20 | |
| 1.11 a | 56.10 a | 10.30 b | 14.61 b | 5.39 a | 0 | **Iron (mg. L-1)** |
| 1.17 a | 59.02 a | 10.83 b | 15.48 b | 5.47 a | 50 | |
| 1.20 a | 59.10 a | 12.10 a | 18.78 a | 5.02 a | 100 | |
| 0.92 c | 46.41 c | 10.63 a | 12.95 c | 4.43 b | 0 | **Manganese saturated with salicylic acid (mg. L-1)** |
| 1.12 b | 56.38 b | 11.41 a | 14.78 b | 4.95 b | 10 | |
| 1.44 a | 72.77 a | 11.18 a | 21.16 a | 6.50 a | 20 | |

Values with similar letters for each factor or its interventions individually are not significantly different according to Duncan's multinomial choice under the probability level.0.05.

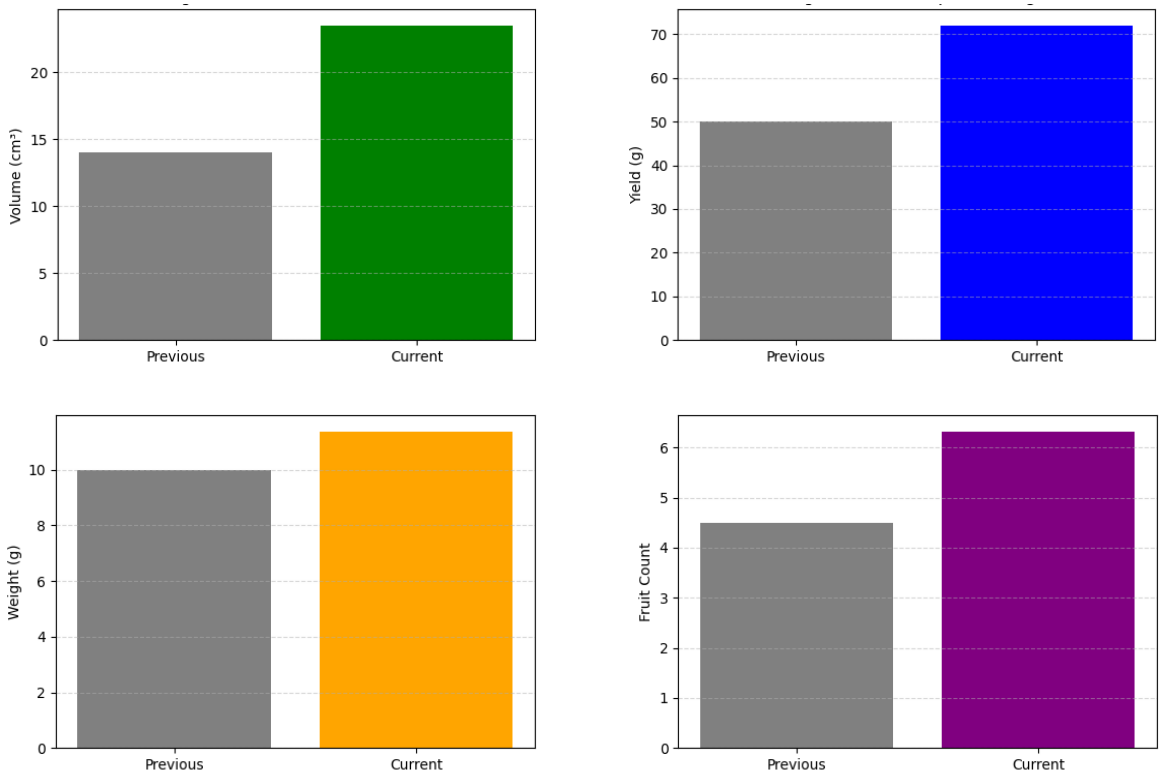


Figure 1. Comparison of fruit characteristics between previous studies and the current study

Figure 1 depicts the relative performance of Shalik fruits in two fertilization systems (1) iron with salicylic acid as used in the past research, and (2) iron with manganese saturated with salicylic acid used in the present experiment. In all the four parameters that include, fruit volume, plant yield, fruit weight and fruit number, the current study yields better results. This means that there is increased physiological and biochemical response in the presence of manganese and salicylic acid and iron. Manganese is known to increase enzyme activity and chlorophyll development whereas salicylic acid leads to stress tolerance and nutrient uptake leading to improved growth of fruits, increased size and improved yield.

The results obtained from this study are explained by the effect of iron on growth in general and on production in particular, as it was recorded In the treatment of spraying with chelated iron 50 mg.L-1, the highest increase in all physical characteristics of the fruit, diameter, length, size, and weight of the fruit, which amounted to (3.80 cm, 1.88 cm, 8.30 g, and 8.58 cm3), respectively, with a significant difference from the comparison treatment. The reason for this is attributed to the role of iron in building nucleic acids and plastids. Which led to an increase in the chlorophyll content in the leaves, which led to an increase in the efficiency of photosynthesis, then an increase in the growth rate by increasing the rates of division and elongation in the cells, and then an increase in the weight of the fruit. Treatment with chelated iron led to an increase in the average shoot weight by increasing the concentrations. The highest average weight was 6.17 kg in the 50 mg.L-1 chelated iron treatment, compared to the lowest average weight of 5.07 kg in the comparison treatment, and this is consistent with.

The role of manganese saturated with salicylic acid in the chemical characteristics of the fruit is clear. A significant increase in Yield per plant (g) and yield per unit area (ton. hectare-1) The 20 mg. L-1 treatment outperformed72.77, 1.44) respectively.

As for the effect of the interaction between iron and manganese saturated with salicylic acid, and from the results that have been reached, it can be concluded that it is possible to stimulate the vegetative and fruiting growth of the shlek plant using spraying with iron and manganese saturated with salicylic acid, and that the best combination between iron and manganese saturated with salicylic acid is100 mg. L-1 of calcium and 20 mg. L-1 of manganese saturated with salicylic acid, which gave the best results for all the studied characteristics.

## Discussion

This article has determined that incorporating salicylic acid to increase the amount of manganese and iron in the same way enhances both growth and yield characteristics of Shalik's fruit (Ahmad et al., 2025; Hemasree et al., 2025). Salicylic acid enhanced fruit size and stage through the use of iron and manganese, as well as through its role in the production of chlorophyll and improving photosynthetic efficiency via increased enzymatic activity associated with photosynthesis. Conversely, though salicylic acid was incorporated into the growth process, an abundance of iron had a direct relationship with yield based upon the short and long-term affects it had on the fruit, such as through increased fruit number, fruit size and overall yield (Mukesh et al., 2024). As the concentrations of manganese (20 mg $L^{-1}$) and iron (100 mg $L^{-1}$) combined with salicylic acid produced the highest performance in all areas measured. Clearly, there is a synergistic response resulting from this combination in terms of yield, productivity, and quality of the fruit. The comparison of the current study with historical literature confirms that the inclusion of manganese (20 mg $L^{-1}$) in combination with salicylic acid provides greater improvements when compared to iron/salicylic acid; therefore, manganese represents a critical factor when maximizing fruit productivity in Shalik.

## Conclusion

The findings of the research are clear: foliar applications of iron or manganese alone do not enhance the quality of Shalik strawberries, but when combined with salicylic acid, both iron and manganese substantially increase the overall fruit development and yield of this variety. Iron is particularly beneficial for increasing the average size and weight of individual strawberries, while manganese combined with salicylic acid significantly increases the total number of fruits produced and therefore, total yield potential. In this study, the combination of 100 mg/L of iron with 20 mg/L of manganese when saturated with salicylic acid represents the optimum treatment for improving all measured fruit attributes and should serve as a viable strategy for improving both quality and yield in strawberry production. Future research should investigate the effects of this treatment regimen under varying growth conditions, and with other strawberry cultivars to confirm its efficacy.

## Author Contributions

All Authors contributed equally.

## Conflict of Interest

The author(s) declare that there is no conflict of interest regarding the publication of this paper. No financial or personal relationships have influenced the study or its results.

## References

Ahmad, M. A., Agha, B. S., Alabade, A. I., Ibraheem, F. F., Alalaf, A. H., Alalam, A. T. S., ... & Meftahizade, H. (2025). Synergistic effects of boron and zinc foliar applications on growth and post-harvest storage attributes of potato (Solanum tuberosum L.) cultivar Argana. *BMC Plant Biology*, *25*(1), 1623.

Akrami, R., Chitsaz, H., & Ahmadi, Z. (2024). Effect of dietary dehydrated sour lemon peel (Citrus limon) powder on metabolic enzymes, serum biochemistry and stress status of rainbow trout (Oncorhynchus mykiss) juvenile. *International Journal of Aquatic Research and Environmental Studies, 4(*1), 91-99. http://doi.org/10.70102/IJARES/V4I1/8

Al-Abidy, B. A., & Al-Janabi, A. S. (2024). Molecular Characterization and Response of GPX Gene Expression of Strawberry Irrigated with Two Types of Water and Spraying with Glutathione and Vitamin B12. *Biopesticides International*, *20*(1).

Àlvarez-Fernàndez, A., Abadía, J., & Abadía, A. (2006). Iron deficiency, fruit yield and fruit quality. *Iron nutrition in plants and rhizospheric microorganisms*, *4*, 85-101.

Boghori, M., & Tabatabai, S. A. (2017). The Effect of Irrigation Intervals and Nitrogenous Fertilizer on the Quantitative and Qualitative Performance of Chamomile. *International Academic Journal of Science and Engineering, 4*(2), 128–134.

Geetha, K. (2024). Integrating Photosynthetic Efficiency Modelling with Crop Yield and Nutritional Forecasting: A Process-Based Approach Toward Global Food Security. *National Journal of Food Security and Nutritional Innovation*, *2*(2), 1-9.

Hemasree, K. R., Sairam, M., Maitra, S., Ray, S., Maheswari, N., Gaikwad, D. J., & DT, S. (2025). Effects of sulphur and zinc on growth and productivity of summer cowpea under conditions of southern Odisha. *Crop Research (0970-4884)*, *60*.

Januszkiewicz, R., Kulczycki, G., & Samoraj, M. (2023). Foliar fertilization of crop plants in polish agriculture. *Agriculture*, *13*(9), 1715. https://doi.org/10.3390/agriculture13091715

Masina Sairam, S. R., Shankar, T., Pal, A., Priya, K. V., & Maitra, S. (2024). Energetics and economics of Rabi maize as influenced by smart nutrient management under South Odisha conditions. *International Journal of Experimental Research and Review*, *44*, 221-233. https://doi.org/10.52756/ijerr.2024.v44spl.019

Mukesh, G., Sairam, M., Maitra, S., Gaikwad, D. J., Sagar, L., & Ray, S. (2024). Agrometeorological indices, physiological growth parameters, and performance of finger millet as influenced by different cultivars under hot and subhumid region of Odisha. *International Journal of Experimental Research and Review*, *42*, 148-161. https://doi.org/10.52756/ijerr.2024.v42.013

Niu, J., Liu, C., Huang, M., Liu, K., & Yan, D. (2021). Effects of foliar fertilization: a review of current status and future perspectives. *Journal of Soil Science and Plant Nutrition*, *21*(1), 104-118.

Ray, S., Maitra, S., Sairam, M., Sameer, S., Sagar, L., Divya, B., & Gitari, H. I. (2025). The nexus between intercropping systems, ecosystem services and sustainable agriculture: A review. *Research on Crops*, *26*(1). https://doi.org/10.31830/2348-7542.2025.ROC-1166

Shah, S. S., Wahab, S., Khan, A., Ahmad, I., Zeeshan, M., Naz, F., & Shinwari, A. S. (2022). Effect of post-harvest application of salicylic acid on the storage stability of peach fruit: application of salicylic acid on peach fruit. *Biological Sciences-PJSIR*, *65*(3), 213-221.

Shahsavar, A. R., Farkhondeh, H., & Sayyad-Amin, P. (2024). The effect of foliar spraying of naphthalene acetic acid, gibberellic acid, kinetin, putrescine and salicylic acid on physicochemical properties of 'Shahabi'date fruit. *Scientific Reports*, *14*(1), 31360.

Shamili, M., Esfandiari Ghalati, R., & Samari, F. (2021). The impact of foliar salicylic acid in salt-exposed guava (Psidium Guajava L.) seedlings. *International Journal of Fruit Science*, *21*(1), 323-333. https://doi.org/10.1080/15538362.2021.1887050

Ssemugenze, B., Ocwa, A., Kuunya, R., Gumisiriya, C., Bojtor, C., Nagy, J., ... & Illés, Á. (2025). Enhancing maize production through timely nutrient supply: The role of foliar fertiliser application. *Agronomy*, *15*(1), 176. https://doi.org/10.3390/agronomy15010176

Sudhandiradevi, S., & Sabin Begum, R. (2025). Enhanced millet crop yield prediction using an optimized hybrid fuzzy logic model. *Journal of Internet Services and Information Security, 15*(2), 351–361. https://doi.org/10.58346/JISIS.2025.I2.025

Veerasamy, K., & Fredrik, E. J. T. (2023). Intelligence System towards Identify Weeds in Crops and Vegetables Plantation Using Image Processing and Deep Learning Techniques. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications, 14*(4), 45-59. https://doi.org/10.58346/JOWUA.2023.I4.004

Whitmore, J., & Fontaine, I. (2024). Techniques for Creating, Extracting, Separating, and Purifying Food and Feed Using Microalgae. *Engineering Perspectives in Filtration and Separation*, 28-33.