

Foliar Nutritive Strategies for Superior Seedling Vigor: Synergistic Effects of Chelated Iron and Magnesium Sulphate on Improving Growth and Nutritional Status of Nemaguard Peach Rootstock Seedlings

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Abstract

This study was conducted at nursery of National Research Centre, Egypt during the 2023 and 2024 seasons to evaluate the effect of foliar applications of chelated iron (10, 20, 30 mg/L) and magnesium sulphate (1, 2, 3 g/L) on the growth and nutritional status of Nemaguard peach rootstock seedlings. Seedlings received three sprays per season at two-week intervals starting mid-June. The results revealed that all treatments significantly enhanced vegetative growth parameters (seedling height, stem diameter, number of leaves per seedling, fresh and dry leaf weight, leaf area and total leaf chlorophyll content) and leaf chemical composition compared to the control. Foliar spraying with magnesium sulphate at 3 g/L (T7) recorded the highest values for seedling height, stem diameter, and carbohydrate content. Meanwhile, chelated iron at 30 mg/L (T4) was superior in leaf nitrogen and iron content. The study concludes that applying magnesium sulphate at 3 g/L and chelated iron at 30 mg/L is the most technically efficient treatment for producing vigorous seedlings ready for grafting within a shorter timeframe.

Introduction

Peach (*Prunus persica* L.) is one of the most economically important stone fruit crops globally. Success of peach orchards significantly depends on the selection of suitable rootstocks, among which Nemaguard (*Prunus persical* X *Prunus davidiana* Carrere) is widely utilized due to its vigorous growth and high resistance to root-knot nematodes, extremely disease resistant and more resistant to the gall crown than other used rootstocks (**Abdel Aziz, 2020**). Also, it's preferred for almonds; due to its significant effect on nutrient absorption, it achieved the highest level of leaf mineral content and a remarkable increase in vegetative growth vigor of two almond varieties, Nonpareil and Ne Plus Ultra almond under Nubaria conditions (**Abou Rayya et al., 2021**). However, producing high-quality rootstock seedlings in nurseries remains a challenge, as it requires optimal nutritional management to reach grafting size within a shorter timeframe (**Rakha et al., 2024; Abou Rayya et al., 2025**).

Foliar fertilization contributes to increasing the efficiency of fertilizer use and improving the growth and production of fruit trees (**Mahmoud et al., 2015; Hegazi et al., 2016 a**). Foliar fertilization has emerged as a crucial technique in modern nursery management, offering a rapid and efficient means of supplying essential nutrients directly to the foliage, bypassing soil-related constraints such as nutrient fixation and leaching to obtain a rapid response due to the high speed at which nutrients are absorbed from the vegetative parts of the plant (**Mahmoud et al., 2017; Chen et al., 2018**). Foliar nutrition containing trace elements (iron, zinc, boron, manganese, and copper) is crucial for providing fruit seedlings with these elements, particularly when the plant cannot easily absorb them through its roots when other fertilizer compounds are added to the soil. The operation of numerous biological processes within the plant, including photosynthesis and the creation of proteins, carbohydrates, and other substances, depends on these elements, which are present in trace amounts. Because of their positive effects on the traits of vegetative growth and the plants' nutrient content, care must be taken to supply the components that plants require (**Fernández et al., 2013**).

Magnesium is a major element that plays a significant role in the photosynthesis; it is an essential component of the chlorophyll molecule (the central atom of the chlorophyll molecule), containing 6.7 percent magnesium and has an important role in plants growth and development (**Mengel and Kirkby, 1987; Abou Rayya et al., 2015**). Magnesium is activator for numerous enzymes involved in carbon fixation and phloem loading of sucrose (**Guo et al., 2016; Tränkner and Jaghdani, 2019**). Deficiency in magnesium directly leads to reduced photosynthetic capacity and stunted vegetative growth (**Hegazi et al., 2016 a**).

According to **Kobayashi and Nishizawa (2012)**, iron is regarded as one of the most significant elements because it plays a part in electron transport during photosynthesis, nitrogen metabolism, and the creation and activation of the chlorophyll pigment through its entry into the porphyrin compounds that comprise chlorophyll. In addition to participating in the synthesis of chloroplasts and the formation of plant proteins, it is also a component of the stochromes responsible for the plant's respiration process (**Gyana and Sunita, 2015**). Iron also enters the synthesis of numerous enzymes, including catalase, peroxidase, and cytochrome oxidase, which activate numerous essential processes within the plant, particularly oxidative reactions, because its significance lies in the transfer of electrons in oxidation reactions (**Havlin et al., 2005**).

Since iron is relatively immobile within plant tissues, periodic foliar applications are often necessary to prevent chlorosis and maintain the structural integrity of chloroplasts in rapidly growing seedlings (**Liu et al., 2020**). Previous studies have indicated that the synergistic application of macro and micronutrients can significantly enhance the carbohydrate accumulation and structural development of trees and seedlings (**Hegazi et al., 2016 b; Wang et al., 2021; Abou Rayya et al., 2025**).

Chelated iron is one of the most widely used forms of iron, as the element is preserved in a form that is easily absorbed and transported by the plant, and many studies have proven its effectiveness in increasing vegetative growth (**El-Hamdani and Al-Ali, 2022; Ajboory and Al-Douri, 2023; Rakha et al., 2024**).

Despite the known benefits of these elements, there is a need to determine the optimal concentrations and timing for foliar applications specifically for Nemaguard seedlings under nursery conditions to accelerate their growth cycle. Therefore, this study aims to evaluate the effect of various concentrations of chelated iron and magnesium sulphate on the vegetative growth, leaf mineral content, and total carbohydrate accumulation of Nemaguard rootstock seedlings.

Materials and Methods

An experiment was conducted in 5 kg plastic culture pots on two-year-old Nemaguard peach seedlings during the years 2023-2024 at National Research Centre in Egypt to study the effect of foliar spraying with Iron and Magnesium on the growth and nutritional status of the seedlings. The plant materials used in this study were obtained from a privately owned orchard with the permission and cooperation of the

orchard owner. No governmental permit or formal collection authorization was required, as the study did not involve protected species or collection from protected areas.

The experiment consisted of seven treatments applied using a randomized complete block design (RCBD) with five replications. **Table (1)** shows the physical and chemical analysis of agricultural soil. The seedlings were sprayed three sprays per season, two weeks between each spray and the next, and the spraying dates were; the first spray on 15th June, the second spray on 30th July, and the third spray on 15th July). The studied traits were recorded two months after the last spray from both seasons.

Treatments:

- T1. Spraying seedlings with water only (control (
- T2. Spraying seedlings with chelated iron at 10 mg/L
- T3. Spraying seedlings with chelated iron at 20 mg/L
- T4. Spraying seedlings with chelated iron at 30 mg/L
- T5. Spraying seedlings with magnesium sulphate at 1 g/L
- T6. Spraying seedlings with magnesium sulphate at 2 g/L
- T7. Spraying seedlings with magnesium sulphate at 3 g/L

All chemicals used for foliar spray solutions, including chelated iron and magnesium sulphate, were obtained from Sigma-Aldrich (St. Louis, MO, USA) and were of analytical grade. All spray solutions were sprayed until they ran off and included 0.1% triton B as a wetting agent to prevent surface tension.

Studied traits

- 1. Seedling height (cm):** Average height of five seedlings per treatment was measured starting from ground level to the main tip using a tape measure.
- 2. Seedling diameter (cm):** Average diameter of five seedlings for each treatment was measured at a height of 10 cm above the ground using the Vernier calipe technique.
- 3. Number of leaves/seedlings:** Average number of leaves of five seedlings per treatment was calculated.
- 4. Leaf area (cm²):** Average area of twenty-five leaves per treatment was measured using a CI-202 portable laser leaf area meter.
- 5. Total chlorophylls (SPAD unit):** Average total chlorophylls content of twenty-five leaves for each treatment was measured in the field using chlorophyll measuring device model SPAD-502.

6. Fresh and dry weight of leaves (g): Average of twenty-five leaves for each treatment was weighed to record the fresh weight, then washed with distilled water and dried in the oven at a temperature of 70°C until a constant weight was reached and weighed to record the dry weight.

7. Total carbohydrate content (%): according to **Dubois et al. (1956)**, the total carbohydrate content in leaves was determined.

8. Determination of leaf mineral content: Prior leaf samples were pulverized in a porcelain mortar to prevent mineral contamination; each sample's 0.5 g of powdered dried material was digested using H₂O₂ and H₂SO₄ in accordance with **Evenhuis and Dewaard's (1980)** guidelines. After that, appropriate aliquots were extracted for mineral analyses.

- Nitrogen (N %): Determined by using micro Kjeldhal as described by **(Pregl, 1945)**.
- Phosphorus (P%): Determined calorimetrically according to **(Chapman and Pratt, 1961)**.
- Potassium (K%): Determined by flame photometer as described by **(Brown and Lilleland, 1974)**.
- Magnesium (Mg ppm), iron (Fe ppm), manganese (Mn ppm), copper (Cu ppm) and zinc (Zn ppm): Measured by atomic absorption according to **(Jackson, 1973)**.

Statistical analysis

According to Snedecor and Cochran (1990), the experimental design was a randomized block design with five replicates, and the data collected from both seasons were examined using ANOVA. According to Duncan (1955), a multiple range test was used to compare the means of the treatments at a 5% level of probability.

Results and Discussion

1. Vegetative growth

The results obtained showed that vegetative growth characteristics of Nemaguard seedlings; height and diameter of seedling, number of leaves/branch, leaf area, fresh and dry weight of leaves, and total leaf chlorophyll content, were significantly affected by treatment with different concentrations of chelated iron and magnesium sulphate during the two study seasons.

1.1. Seedling height

Figure 1 shows a significant increase in seedling height as a result of foliar spraying with different concentrations of both fertilizers compared to control (spraying with water only). This increase was directly proportional to the concentration across both seasons. The highest seedling height was observed in (T7) foliar spraying with magnesium sulfate at 3 g/L (105 and 114 cm in the first and second seasons, respectively), followed by (T3) foliar spraying with chelated iron at 30 mg/L (99.33 and 102 cm

in the first and second seasons, respectively). The control treatment (T1) recorded the lowest seedling height (80.67 and 81 cm in the first and second seasons, respectively).

1.2. Stem Diameter

Results presented in **Figure (1)** indicate a significant effect of foliar application of chelated iron and magnesium sulphate on stem diameter compared with control treatment (T1) during both growing seasons 2023 & 2024. Control seedlings treated with water only (T1) recorded the lowest stem diameter values (0.40 and 0.45 cm) in the first and second seasons, respectively, reflecting limited vegetative growth in the absence of nutrient application.

Foliar application of chelated iron resulted in a gradual increase in stem diameter with increasing concentration. Stem diameter increased from 0.40 cm at 10 mg/L (T2) to 0.43 cm at 20 and 30 mg/L (T3 and T4) in the first season, while in the second season the highest value (0.57 cm) was recorded at 30 mg/L (T4).

In contrast, magnesium sulphate treatments showed a more pronounced effect on stem diameter than chelated iron. Stem diameter increased progressively with increasing magnesium sulphate concentration, reaching (0.47, 0.50, and 0.57 cm) in the first season for T5 (1 g/L), T6 (2 g/L), and T7 (3 g/L), respectively. A similar trend was observed in the second season, with the highest stem diameter (0.60 cm) recorded at 3 g/L magnesium sulphate (T7), followed by (T6) magnesium sulphate at 2 g/L (0.57cm).

Overall, foliar spraying with magnesium sulphate at 3 g/L (T7) was the most effective treatment for enhancing stem diameter in Nemaguard seedlings during both seasons, followed by chelated iron at the highest concentration.

The significant enhancement in seedling height and diameter are primarily attributed to the synergistic effect of magnesium and iron on the primary metabolism of the plant. The superiority of magnesium (T7) is due to its role in increasing the rate of cell division and elongation in the apical meristem, as magnesium is a critical cofactor for enzymes involved in DNA and RNA synthesis (**Guo et al., 2016**). Furthermore, magnesium facilitates the translocation of photosynthetic products from source leaves to the growing vegetative sinks, providing the energy required for vertical growth (**Verbruggen and Hermans, 2013**). The positive impact of iron (T4) on height and diameter can be explained by its essential role in the electron transport chain during photosynthesis and its contribution to the biosynthesis of growth-promoting hormones like auxins and gibberellins (**Marschner, 2012; Liu et al., 2020**). These findings are consistent with the increase in nitrogen and carbohydrate levels observed in the study, which collectively support the structural development and height of the seedlings (**Wang et al., 2021**).

1.3. No of leaves/seedling

Figure 2 illustrates that number of leaves per Nemaguard seedling increased significantly as a result of foliar spraying with chelated iron and magnesium sulphate during both study seasons, particularly at the higher concentrations in both seasons compared to the control group. Chelated iron treatments resulted in a progressive increase in number of leaves with increasing concentration, rising from (142.33 leaves / seedling) at 10 mg/L to (157.67 leaves / seedling) at 30 mg/L in the first season, with a similar trend in the second season.

Regarding the magnesium sulphate spraying, the treatments showed a clear advantage over the iron treatments, as number of leaves increased with increasing concentration from 10 mg/L to 30 mg/L, reaching (162.67, 172.67, and 177.67 leaves / seedling) in the first season for treatments T5, T6, and T7, respectively. In the second season, magnesium sulphate treatments continued to outperform, registering T7 (196 leaves/seedling), followed by T6 (179 leaves/seedling).

In general, it was observed that increasing the concentration of both fertilizers led to a significant increase in the number of leaves per seedling during both study seasons, with magnesium sulphate foliar applications showing a clear advantage (T7). These results confirm the important physiological role of both iron and magnesium in stimulating vegetative growth and increasing leaf formation.

The physiological superiority of magnesium over iron in increasing leaf formation stems from its fundamental roles in photosynthesis and vegetative growth. As the central atom in the chlorophyll molecule, magnesium availability directly enhances chlorophyll biosynthesis and photosynthetic efficiency, thereby increasing carbohydrate production essential for new leaf development (**Marschner, 2012; Wang et al., 2020**). Additionally, magnesium acts as a vital activator for numerous enzymes involved in protein and nucleic acid synthesis, which accelerates cell division and elongation in developing buds (**Guo et al., 2016**).

Furthermore, magnesium is crucial for the phloem loading of sucrose and its subsequent transport from source leaves to active sinks (growing tips), providing the necessary energy and building blocks for efficient leaf formation (**Verbruggen and Hermans, 2013; Chen et al., 2018**). It also maintains cellular ionic balance and prevents the feedback inhibition of photosynthesis by facilitating the export of carbohydrates from mature leaves (**Tränkner et al., 2018**).

In contrast, while iron is essential for chlorophyll synthesis and electron transport, its role is more specialized and primarily impacts the intensity of greening and photosynthetic quality. Iron limited mobility within the plant tissues (immobility) restricts its immediate impact on new leaf initiation compared to the more mobile and multifaceted role of magnesium (**Römheld and Marschner, 1991; Kobayashi and Nishizawa, 2012**). Consequently, magnesium integrated effects on metabolism, translocation, and cell division explain its clear superiority over iron in promoting leaf formation in Nemaguard seedlings.

1.4. Leaf area

Figure 2 shows that foliar spraying with chelated iron and magnesium sulfate significantly increased the leaf area of Nemaguard rootstock seedlings compared to the control treatment during both seasons of the study.

The control treatment (T1) recorded the lowest leaf area values in both seasons, reflecting the limited leaf growth in the absence of fertilizer application. The chelated iron treatments resulted in a gradual improvement in leaf area with increasing concentration, with values rising from T2 to T4, and the highest concentration treatments showing the greatest improvement.

The magnesium sulphate treatments showed a more pronounced effect compared to the iron treatments, with treatments T5, T6, and T7 recording the highest leaf areas, although no significant differences were observed between them, particularly in the second season. Overall, the magnesium sulphate spray treatment at the highest concentration (T7) resulted in the highest leaf area in both seasons.

The significant expansion in leaf area observed in treated seedlings can be attributed to the pivotal physiological roles of magnesium and iron in cellular development and biomass accumulation. The superiority of magnesium sulphate (T7) is primarily due to magnesium role as a cofactor for DNA and RNA polymerases, which accelerates cell division and multiplication in leaf primordia (**Guo et al., 2016**). Additionally, magnesium is essential for maintaining turgor pressure within plant cells, which serves as the primary driving force for cell elongation and leaf blade expansion (**Tränkner et al., 2018**). Furthermore, the increase in leaf area is closely linked to the enhanced chlorophyll content and photosynthetic capacity associated with magnesium (central atom of chlorophyll) and iron (a catalyst in chlorophyll biosynthesis) (**Wang et al., 2020**). This improvement in the photosynthetic apparatus facilitates the production of larger quantities of carbohydrates, providing the necessary energy and carbon skeletons for structural growth (**Wang et al., 2021**). The higher nitrogen levels recorded in iron-treated seedlings also contribute to the synthesis of structural proteins required for leaf tissue formation (**Liu et al., 2020**).

1.5. Leaf fresh weight

Figure 3 illustrates the effect of foliar application of chelated iron and magnesium sulphate on leaf fresh weight (g) of Nemaguard seedlings during the two growing seasons. The control treatment (T1), sprayed with water only, recorded the lowest leaf fresh weight in both seasons. In contrast, foliar application of chelated iron (T2–T4) significantly increased leaf fresh weight compared with the control, with a gradual increase observed as iron concentration increased.

Magnesium sulphate treatments (T5–T7) showed a more pronounced effect, resulting in the highest leaf fresh weight values, with no significant differences among the higher concentrations, particularly in the second season. Overall, foliar spraying with magnesium sulphate, especially at 3 g/L (T7), was the most effective treatment in enhancing leaf fresh weight, and values were generally higher in the second season than in the first.

1.6. Leaf dry weight

The results presented in **Figure 3** show that foliar application of chelated iron and magnesium sulphate significantly increased **leaf dry** weight of Nemaguard seedlings compared with the control in both seasons. The control treatment (T1) recorded the lowest leaf dry weight, indicating limited dry-matter accumulation in the absence of nutrient supplementation. Foliar sprays of chelated iron (T2–T4) led to a progressive increase in leaf dry weight with increasing iron concentration, with the highest values observed at 30 mg L⁻¹ (T4). Magnesium sulphate treatments (T5–T7) produced the greatest increases in leaf dry weight, with the highest values obtained at 3 g L⁻¹ (T7) in both seasons. In general, leaf dry weights were higher in the second season than in the first, reflecting improved physiological performance over time.

The enhancement of leaf dry weight by foliar iron application can be attributed to the essential role of iron in chlorophyll biosynthesis and electron transport during photosynthesis, which enhances carbon assimilation and dry-matter production (**Briat et al., 2015; Ghasemi et al., 2021**). However, the superior performance of magnesium sulphate treatments is consistent with the central role of magnesium as the **core atom of chlorophyll** and as an activator of key enzymes involved in carbon fixation and carbohydrate metabolism (**Hermans et al., 2013; Cakmak, 2014**). Magnesium also facilitates phloem loading and translocation of photosynthates, leading to greater accumulation of structural carbohydrates and biomass (**Guo et al., 2020**). These combined physiological effects likely explain the pronounced increase in leaf dry weight in magnesium-treated seedlings compared with those receiving iron alone.

1.7. Total chlorophyll leaf content

Figure 4 illustrates the effect of foliar application of chelated iron and magnesium sulphate on **total leaf chlorophyll content (SPAD units)** of *Nemaguard* rootstock during the first and second seasons.

The results indicate that the control treatment (T1), sprayed with water only, recorded the lowest chlorophyll content in both seasons, reflecting limited photosynthetic capacity under nutrient deficiency. Foliar application of **chelated iron** (T2–T4) significantly increased total chlorophyll content compared with the control, with a gradual increase observed as iron concentration increased. This response is attributed to the essential role of iron in chlorophyll biosynthesis and in activating enzymes involved in photosynthetic electron transport (**Briat et al., 2015**).

In contrast, **magnesium sulphate treatments** (T5–T7) resulted in the highest chlorophyll content, particularly at the highest concentration (3 g L⁻¹; T7), which recorded the maximum SPAD values in both seasons. Magnesium plays a direct and critical role as the central atom of the chlorophyll molecule and acts as an activator of several enzymes associated with carbon fixation and energy transfer, leading to enhanced chlorophyll accumulation and photosynthetic efficiency (**Cakmak, 2014**). Moreover, adequate magnesium nutrition improves carbohydrate translocation and overall leaf metabolic activity, which further supports chlorophyll stability and synthesis (**Hermans et al., 2013**).

Overall, chlorophyll content was generally higher in the second season than in the first, indicating a cumulative positive effect of improved mineral nutrition. The superior performance of magnesium sulphate over chelated iron highlights the pivotal role of magnesium in chlorophyll formation and photosynthetic performance of Nemaguard seedlings.

2. Nutritional status

2.1. Total carbohydrate leaf content

Results presented in **Figure (4)** demonstrate a significant impact of foliar applications of chelated iron and magnesium sulphate on the total carbohydrate content of Nemaguard rootstock leaves during both seasons.

The control treatment (T1) exhibited the lowest carbohydrate percentages. In contrast, the application of magnesium sulphate at 3 g/L (T7) yielded the highest carbohydrate accumulation, reaching approximately (3.6 and 3.75%) in the first and second seasons, respectively. Overall, magnesium sulphate treatments outperformed chelated iron treatments in enhancing leaf carbohydrate levels.

The significant increase in carbohydrate content following magnesium sulphate application can be attributed to the fundamental role of magnesium as the central atom of the chlorophyll molecule, which directly enhances photosynthetic efficiency (**Marschner, 2012; Guo et al., 2020**). Furthermore, magnesium acts as a vital cofactor for enzymes involved in carbohydrate metabolism and is essential for phloem loading of sucrose (**Mengel and Kirkby, 1987**). The positive response to chelated iron (T2-T4) is likely due to its essential role in the biosynthesis of cytochromes and ferredoxin, which are critical for electron transport during photosynthesis, thereby promoting the accumulation of total carbohydrates (**Römheld and Marschner, 1991; Nabila et al., 2015**).

2.2. Leaf mineral content

The results shown in **Tables (2 & 3)** reflect the correlation between the concentration of the studied macro and micronutrients absorbed in the leaves of Nemaguard rootstock seedlings and the different treatments with chelated iron and magnesium sulphate during the 2023 & 2024 growing seasons.

2.2.1. Leaf macronutrients

Nitrogen (N %): The results showed that foliar spraying with chelated iron at a concentration of 30 mg/L (T4) significantly outperformed all other treatments, recording the highest nitrogen levels (1.15% and 1.24%) in the two seasons, respectively (**Table 2**).

Phosphorus (P %): Treatment (T7) magnesium sulphate at a concentration of (3 g/L) recorded the highest phosphorus accumulation in the leaves, reaching (0.62%) in the second season, significantly exceeding the control (**Table 2**).

Potassium (K %): A progressive increase was observed with increasing magnesium concentration, with treatment (T7) recording the highest potassium values (2.12 and 2.21%) in the first and second seasons, respectively (**Table 2**).

Magnesium (Mg ppm): Leaf magnesium content **Table (2)**, naturally increased with increasing magnesium sulphate concentration, with treatment (T7) recording the highest value of (20.63 and 20.80 ppm) in the first and second seasons, respectively.

2.2.2. Leaf micronutrients

Iron (Fe): Treatment with chelated iron at a concentration of 30 mg/L (T4) resulted in the highest level of iron uptake in leaf tissues, at 69.09 ppm, in the second season (**Table 3**). Manganese (Mn), Zinc (Zn), and Copper (Cu): Treatment T7 (high magnesium) was superior in stimulating the uptake of these three elements, recording (49.47 ppm for manganese, 22.20 ppm for zinc, and 16.05 ppm for copper in the second season. In contrast, the control treatment (T1) recorded the lowest values for all micronutrients, confirming the need for foliar fertilization of Nemaguard rootstock to compensate for nutrient deficiencies (**Table 3**). The superiority of spraying with chelated iron at 30 mg/L (T4) in increasing leaf nitrogen content is likely due to the role of iron as a cofactor for the enzymes Nitrate Reductase, which facilitates nitrogen assimilation (**Marschner, 2012; Liu et al., 2020**). These enzymes are responsible for converting nitrates to ammonium and then to proteins, thus increasing the total nitrogen content of the leaf. Furthermore, the superiority of spraying with magnesium sulphate 3 g/L (T7) in increasing the uptake of (P, K, Cu, Zn, Mn) is explained by magnesiums activation of phosphorylation and ATP-ase enzymes present in cell membranes (**Guo et al., 2016**). These enzymes provide the energy necessary for the active transport of mineral elements from leaf tissues into the living cells.

These findings align with the principle that improving photosynthetic capacity through micronutrient fertilization enhances overall nutrient uptake (**Chen et al., 2018**). Also, **Tables (2&3)** show a direct relationship between the concentration of macro and micronutrients and carbohydrate content (**Figure 4**). The availability of these elements ensures high efficiency in photosynthesis and carbohydrate synthesis (**Wang et al., 2021**).

Our results are consistent with **El-Khawaga (2007); Hegazi et al. (2016 a), Mahmoud et al. (2017)**, who found that sprayed magnesium sulphate significantly increased vegetative growth, photosynthetic pigments, leaf mineral contents (N, P, K and Mg), carbohydrates content in leaves.

These findings agree with **El-Hamdani and Al-Ali (2022); Ajboory and Al-Douri (2023); Rakha et al. (2024)**, who reported that foliar spraying chelated iron led to increase significantly all characteristics of vegetative growth, including seedling height, seedling diameter, number of branches/seedlings, number of leaves/seedlings, leaf area, total chlorophylls, and fresh and dry weight of leaves. It also increased significantly the total carbohydrates and mineral content of leaves (N, K, P, Fe, Mg, Mn, Cu, and Zn).

Conclusion, Recommendations, and Future Research

From the obtained results, we recommend nursery owners and fruit tree seedling producers adopt foliar spraying with magnesium sulphate at a concentration of 3 g/L and chelated iron at 30 mg/L three sprays, two weeks between each spray and the next, starting mid-June, as an effective strategy to enhance the vegetative growth parameters (seedling height, stem diameter, number of leaves and leaf area) of Nemaguard peach rootstock. These treatments have demonstrated high efficiency in increasing leaf chlorophyll and mineral content and promoting the accumulation of total carbohydrates. This approach ensures the production of vigorous seedlings with an optimal nutritional status, ready for grafting operations within a shorter timeframe.

Further studies are recommended to investigate the effects of applying higher concentrations than those used in the present study. Should these concentrations result in statistically significant improvements in the evaluated traits, their practical adoption may be considered. However, if no significant differences are observed compared with the current concentrations, maintaining the levels recommended in this study would be scientifically and practically justified.

Declarations

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Author Contribution

S.A. conceived and designed the study, supervised the field experiment, secured research oversight, interpreted the results, and critically revised the manuscript. N.K. contributed to the experimental design, coordinated and participated in the field experiment, assisted in data interpretation, and reviewed the manuscript. T.M. participated in conducting the field experiment, collected and organized the experimental data, performed the literature review, and contributed to manuscript editing. A.A. coordinated the field experiment, performed the statistical analysis, prepared the figures and tables, wrote the original draft of the manuscript, and managed the manuscript revision process. A.R. participated in the field experiment, assisted with data collection and validation, contributed to the interpretation of the findings, and critically reviewed and edited the manuscript. All authors discussed the results, reviewed the manuscript, and approved the final version for publication.

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Figures

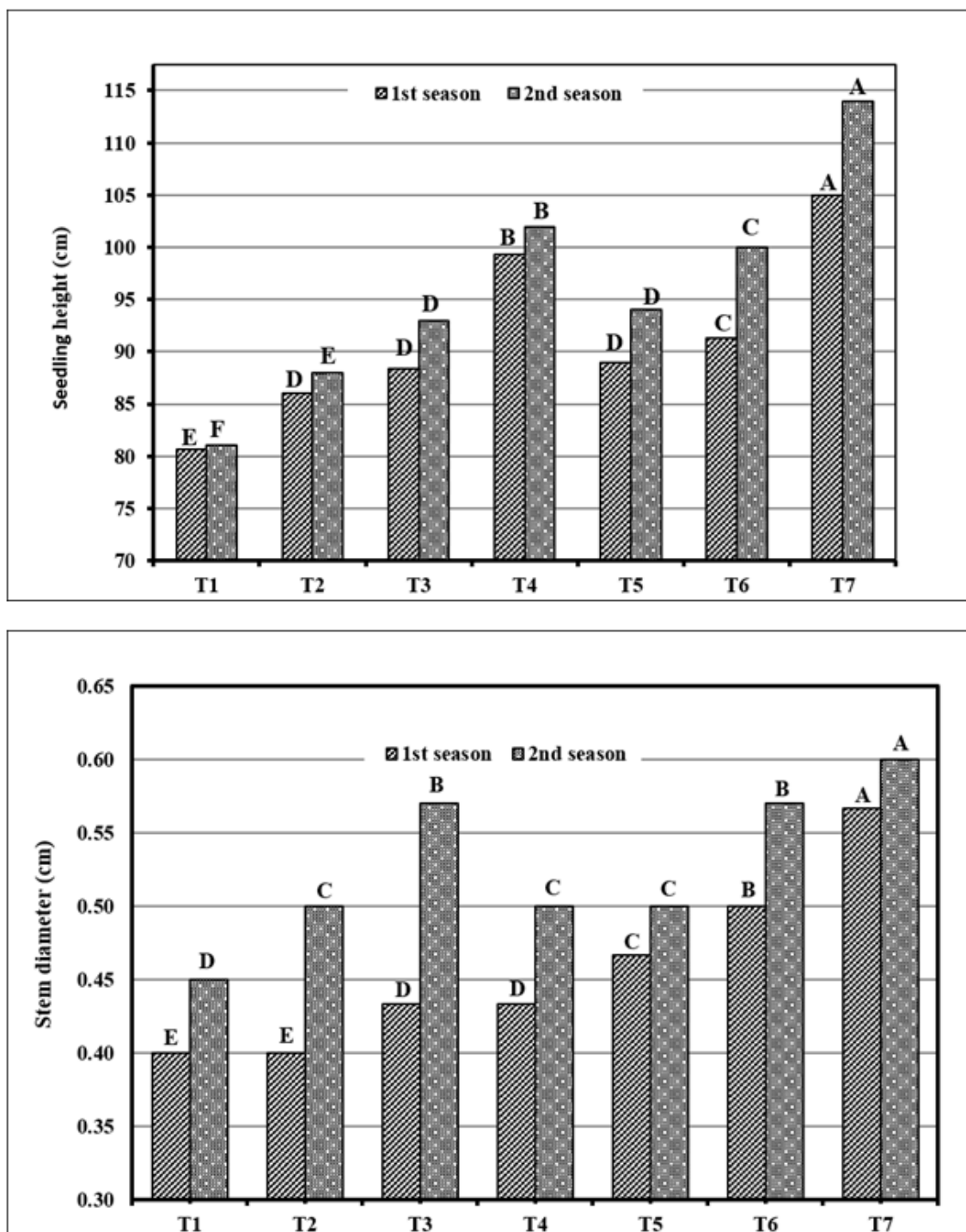


Figure 1

Effect of foliar spraying chelated iron and magnesium sulphate on seedling height and stem diameter of Nemagaurd rootstock during first and second seasons

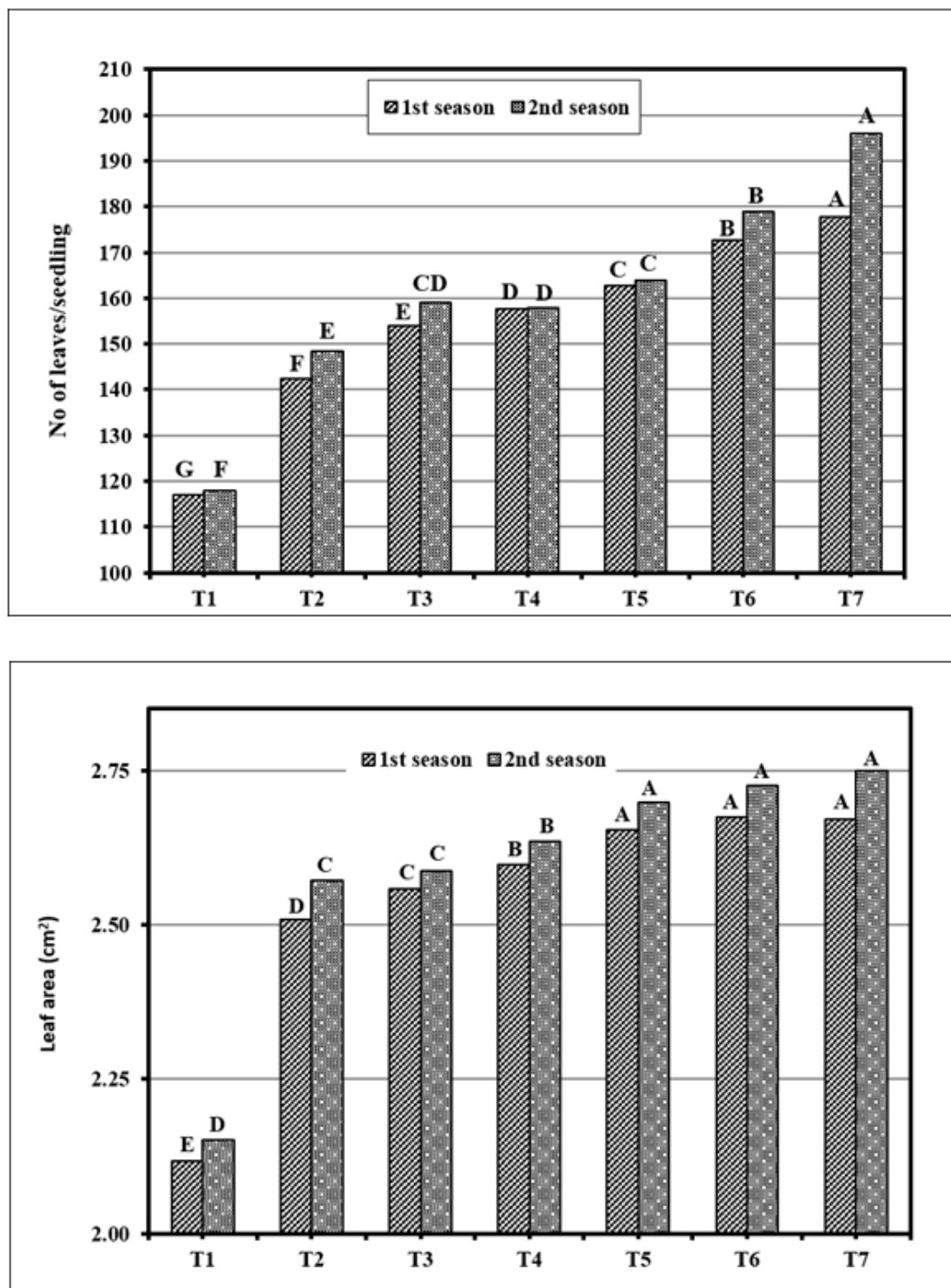


Figure 2

Effect of foliar spraying chelated iron and magnesium sulphate on No of leaves/seedling and leaf area of Nemagaurd rootstock during first and second seasons

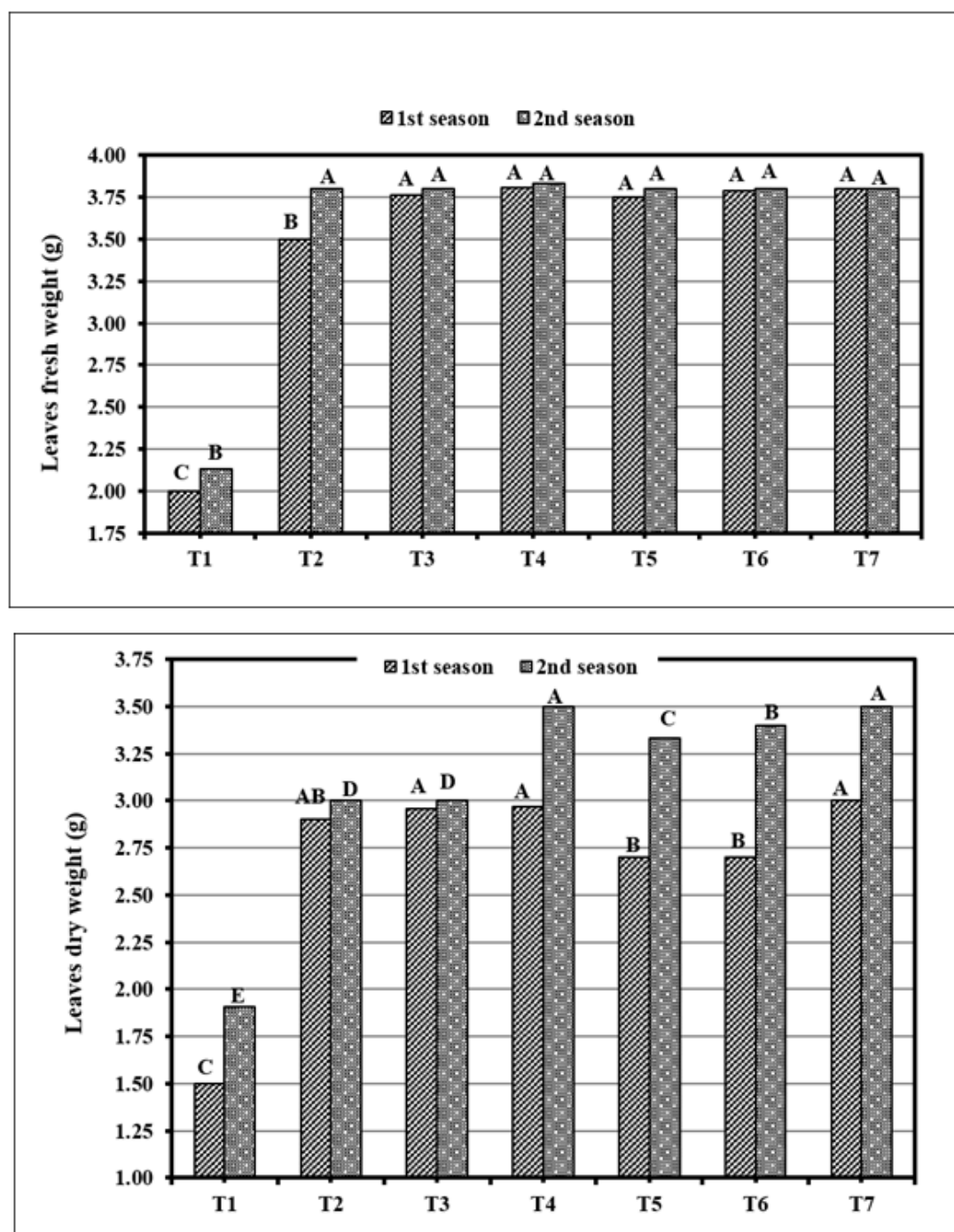


Figure 3

Effect of foliar spraying chelated iron and magnesium sulphate on leaves fresh and dry weight of Nemagaurd rootstock during first and second seasons

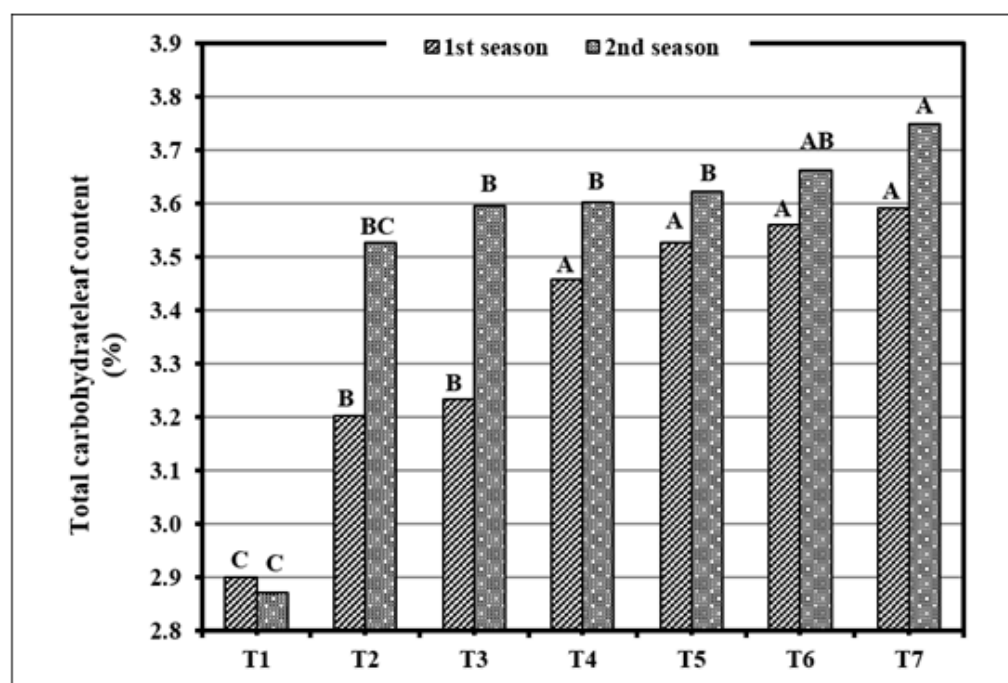
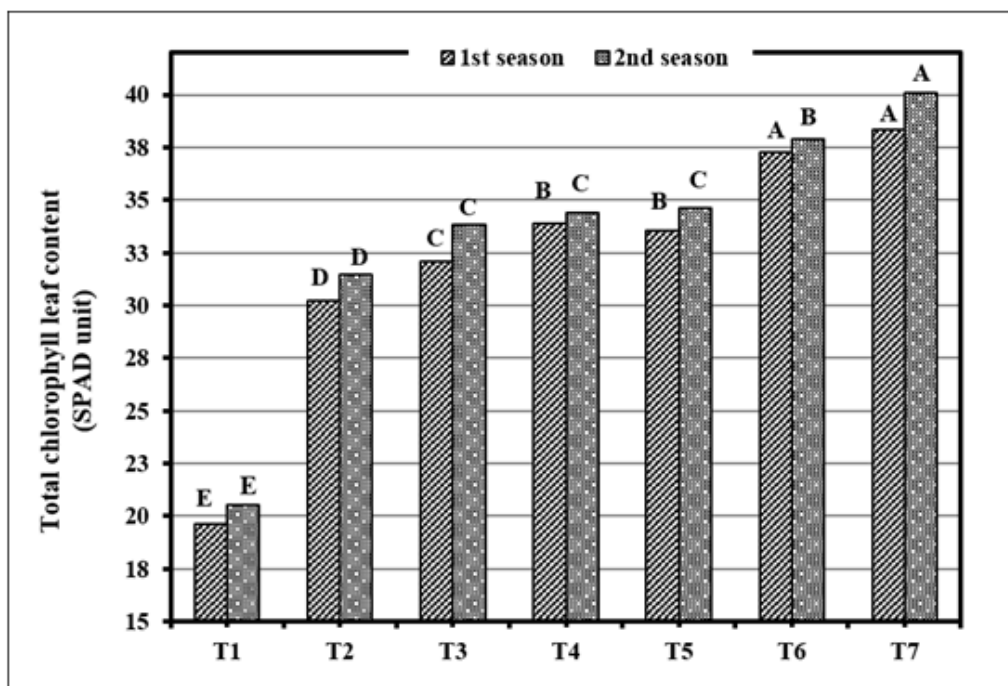


Figure 4

Effect of foliar spraying chelated iron and magnesium sulphate on total chlorophyll and carbohydrate leaf content of Nemagaurd rootstock during first and second seasons