GMR
The Original

CHEMICAL AND NUTRITIONAL RESPONSE OF TWO LOCAL APRICOT VARIETIES (ZANJILI AND ZAGNIA) TO FOLIAR APPLICATION OF NUTRIENTS AND MELATONIN

Zeina Sami Rashid[1] and Huda Abbas Hassan[2]

[1]Department of Horticulture and Landscape Architecture, College of Agriculture, University of Diyala, Iraq; [2]Diyala Agriculture Directorate, Ministry of Agriculture, Iraq.
Corresponding author email: hodaabbas@uodiyala.edu.iq
ORCID: Zeina Sami Rashid https://orcid.org/0000-0001-6855-4278
Huda Abbas Hassan https://orcid.org/0009-0002-9830-3976

ABSTRACT
This study was conducted in a private orchard in Diyala Governorate, Iraq, on eight-year-old apricot trees of the Zanjili and Zagnia varieties, during the 2024 and 2025 growing seasons, with the aim of demonstrating the response of the chemical and nutritional composition of the fruits of the two varieties to foliar spraying with nutrients (calcium oxide at a concentration of 20 g L^{-1}, boron at a concentration of 300 mg L^{-1}, and sorbitol at a concentration of 30 g L^{-1}) and melatonin at three concentrations (0, 50, 100 mg L^{-1}). The experiment was conducted using a split plot design within a randomized complete block design (RCBD) as a factorial experiment with three factors and three replications, with 72 experimental units. The results were analyzed using the SAS statistical software, and the means were compared according to Duncan's multiple range test at a probability level of 0.05. The results showed that the Zagnia variety was significantly superior in the percentage of total soluble solids, total sugars, their ratio to acidity, total phenols, and the boron content of the fruit, while the Zanjili variety was superior in the sorbitol and vitamin C content of the fruit and the higher acidity percentage. No significant difference was found between the two varieties in the carotene content of the fruit peel. The sorbitol spray treatment was characterized by its clear superiority in most of the fruit's chemical properties (soluble solids, total sugars and their ratio to acidity, total phenols, vitamin C, carotene, and the fruit's sorbitol content itself). The boron spray treatment was superior in increasing the fruit's boron content, while the calcium oxide spray treatment was superior in increasing the fruit's calcium content. Spraying with melatonin at a concentration of 100 mg/L^{-1} resulted in the highest values for most of the studied chemical properties and the lowest acidity, followed significantly by a concentration of 50 mg/L^{-1}. The no-spray treatment yielded the lowest values and the highest acidity. The results of the three-way interaction showed that the Zagnia variety, treated with sorbitol and melatonin at a concentration of 100 mg/L, exhibited superiority in most of the fruit's chemical properties (soluble solids, sugars and their acid-to-sugar ratio, and phenols). The Zanjili variety, treated with sorbitol and melatonin at a concentration of 100 mg/L, showed superiority in vitamin C, carotene, and sorbitol content. The Zagnia variety, treated with boron and melatonin at a concentration of 100 mg/L, showed superior boron content in the fruit, while the Zanjili variety, treated with calcium oxide and melatonin at a concentration of 100 mg/L, showed superior calcium content in the fruit. This confirms a clear synergistic effect between the variety, the nutrients, and melatonin in improving the chemical and nutritional composition of the two studied apricot varieties.

KEYWORDS: *Apricot, chemical composition, soluble solids, vitamin C, phenols, sorbitol, melatonin.*

INTRODUCTION
The apricot (Prunus armeniaca L.) is one of the most important stone fruit trees belonging to the Rosaceae family. Its nutritional importance stems from its richness in sugars and vitamins, particularly vitamins A and C, in addition to minerals, phenolic compounds, and carotenoids with antioxidant activity, which enhances its health and nutritional value (Sharma et al., 2021). The market and nutritional quality of apricots is primarily determined by their chemical composition, specifically the percentage of total soluble solids, sugars, acidity, phenolic compounds, vitamin C, carotenoids, and minerals such as boron and calcium. These characteristics are significantly affected by foliar feeding and the growth regulators used during the growing season.
Local Iraqi varieties, including the Zanjili and Zagnia, are characterized by good quality traits in terms of taste and drying suitability (Central Statistical Organization, 2022). However, information regarding the response of their chemical composition to foliar spraying with nutrients and melatonin remains limited under local environmental conditions. Calcium plays a crucial role in strengthening cell walls and pectin sheets, which is reflected in fruit firmness, tissue integrity, and reduced post-harvest deterioration (White and Broadley, 2003). Recent studies have also shown that foliar spraying with calcium compounds improves total soluble solids in apricot fruits (Moradinezhad and Dorostkar, 2021; Al-Saif et al., 2025).

As for boron, a trace element essential for sugar translocation and cell wall formation, foliar spraying directly impacts its fruit content due to its limited internal mobility within the plant (Marschner, 2012; Al-Janabi, 2024). Sorbitol is the primary photosynthetic byproduct in rose family trees and plays a direct role in the accumulation of sugars, total soluble solids, and secondary compounds in fruits (Lo Bianco and Rieger, 2002). Melatonin, a potent antioxidant and multifunctional plant regulator, contributes to regulating fruit ripening and improving its content of phenolic compounds, vitamin C, and carotenoids (Arnao and Hernández-Ruiz, 2019; Zhao et al., 2021). Combined spraying with melatonin and arginine, along with zinc and iron nano-chelates, improved the vitamin C and soluble sugar content of apricot fruits in Iraq (AL-Qady et al., 2025).
Based on the foregoing, and given the limited number of studies examining the chemical and nutritional composition of the fruits of the Zanjili and Zagnia varieties together to combined foliar spraying with calcium oxide, boron, sorbitol, and melatonin, this research complements previous studies that addressed the vegetative, yield, and physical characteristics of the fruits. It focuses on the chemical and nutritional composition of the fruits in terms of soluble solids, sugars, acidity, phenols, vitamin C, carotenes, and the boron, calcium, and sorbitol content.

Nutritional Value of Apricots and Their Local Varieties
Apricots contain high levels of sugars and vitamins, particularly vitamins A and C, in addition to minerals, phenolic compounds, and carotenoids with antioxidant activity (Sharma et al., 2021). The study by Al-Jubouri and Al-Obaidi (2022) showed that the Zagnia variety has a high content of total sugars and phenolic compounds compared to some other local varieties, which highlights its nutritional and economic value. The study by Hussein and colleagues (2023) also confirmed its high quality characteristics and good storage capacity under cooling conditions.
The Effect of Calcium on Fruit Chemical Composition
Calcium contributes to strengthening the cell wall and pectin sheets, thus reducing fruit drop and increasing firmness and resistance to post-harvest damage (White and Broadley, 2003). A study by Shahid et al. (2020) on peaches showed that spraying with 3% calcium chloride raised the total soluble solids to 11.0 Brix. Mehnigar et al. (2018) on pears demonstrated that 0.30% calcium chloride improved acidity and reduced physiological weight loss. Dhali et al. (2024) also indicated that calcium chloride preserved the vitamin C content of fruits during storage. Calcium translocation to fruits is enhanced when combined with treatments that promote phloem movement, such as sorbitol (Guirao et al., 2025).
Calcium translocation to fruits is further enhanced when combined with treatments that promote phloem movement, such as sorbitol (Guirao et al., 2025). The Effect of Boron on the Chemical Composition of Fruits
Boron is a relatively immobile element in plant tissue. Therefore, foliar spraying is the most effective way to directly increase its concentration in fruits (WSU Tree Fruit Boron, 2024). Furthermore, it plays a role in improving carbohydrate translocation and increasing total soluble solids and sugars (Hathi et al., 2019). In a study on the Iraqi Zagonia cultivar, foliar spraying with boron trioxide nanoparticles combined with gibberellic acid resulted in a significant improvement in fruit quality (Al-Janabi, 2024).
The Effect of Sorbitol on Fruit Chemical Composition
Sorbitol constitutes 60-80% of the photosynthetic products transported through the phloem in rose family trees (Cheng et al., 2018). External spraying with sorbitol increases its concentration in the vascular tissue and stimulates the translocation of carbohydrates and minerals to developing fruits. This explains the increased calcium and boron content in fruits treated with sorbitol (Guirao et al., 2025). Furthermore, as an osmotic regulator, sorbitol contributes to protecting fruit tissues from oxidative stress and enhancing their content of phenolic compounds and antioxidants. These findings are consistent with the reported improvement in the quality characteristics of grapes when sorbitol is applied before harvest (Guirao et al., 2025).
The effect of melatonin on the chemical composition of fruits: Melatonin acts as a powerful antioxidant, protecting tissues from oxidative damage during ripening (Ikram et al., 2024). It also stimulates secondary metabolic pathways and increases the activity of enzymes synthesizing phenolic compounds. Furthermore, it stimulates the action of antioxidant enzymes such as peroxidase and catalase, which limit the breakdown of vitamin C and carotenoids during ripening (Ikram et al., 2024). Melatonin also contributes to regulating the activity of enzymes that break down organic acids, such as maleic dehydrogenase, thus accelerating the conversion of acids to sugars and increasing the sugar-to-acid ratio (Hojjati et al., 2024). These results are consistent with those of Carrión-Antolí et al. (2021, 2022), who found an increase in total soluble solids, a decrease in titrable acidity, and an increase in bioactive compounds in melatonin-treated sweet cherry fruits. They also align with the findings of AL-Qady et al. (2025), who observed an increase in vitamin C and soluble sugar content in apricot fruits sprayed with melatonin, arginine, and nano-chelates.

Problem of the Study: Scientific information regarding the chemical and nutritional composition response of the Zanjili and Zagnia apricot varieties to foliar spraying with calcium oxide, boron, sorbitol, and melatonin remains limited. Furthermore, the optimal interactions between these substances to achieve the highest chemical and nutritional quality of the fruit under local environmental conditions are not yet fully understood.

Objectives of the Study:
To investigate the effect of foliar spraying with calcium oxide, boron, sorbitol, and melatonin on the chemical composition of the Zanjili and Zagnia apricot varieties. • Evaluate the response of the two varieties in terms of fruit content of total soluble solids, sugars, acidity, phenols, vitamin C, and carotene.
•Demonstrate the effect of the treatments on the fruit content of minerals (boron and calcium) and sorbitol.
•Determine the effect of the interaction between nutrients and melatonin on improving the chemical and nutritional quality of the fruit.
• Identify the optimal spray treatment that contributes to improving the nutritional and market value of apricot fruits.

MATERIALS AND METHODS OF WORK

Study Site and Experimental Design

The experiment was conducted in one of the private orchards located in the Al-Abara area (Had Mkasar village - Military District) in Diyala Governorate, on eight-year-old apricot trees of the Zanjili and Zaghnia varieties, during the period from 1/1/2024 to 1/7/2025. The experiment was conducted using a split-plot design within a randomized complete block design (RCBD) as a three-factor experiment: variety (Zanjili and Zagnia), nutrients (control, calcium oxide 20 g L^{-1}, boron 300 mg L^{-1}, sorbitol 30 g L^{-1}), and melatonin (0, 50, and 100 mg L^{-1}). This resulted in 24 treatments distributed across three replicates, totaling 72 experimental units. The experiment was repeated in the 2024 and 2025 growing seasons.

Calcium oxide was sprayed three times after 80% of the flowers had opened, with a two-week interval between each application, according to Wahab et al. (2016), and boron (in the form of boric acid) was sprayed three times at the red bud stage, at full flowering, and two weeks after fruit set according to Ödemiş & Uncu (2022). Sorbitol was sprayed four times at the red bud stage, at flowering, after vegetative bud opening, and four days before harvest according to Talang et al. (2017). Melatonin was sprayed three times (after kernel hardening, at the end of the discoloration stage, and four days before harvest) according to Cortes-Montaña et al. (2023).
It should be noted that caution is necessary when using calcium oxide at this concentration, as it may cause damage to leaves and fruit in hot conditions. Therefore, it is recommended to monitor the trees after spraying and reduce the concentration if necessary in subsequent studies.

Orchard Soil Properties

Table 1: Some Chemical and Physical Properties of Apricot Orchard Soil Before the Start of the Experiment

The measured attribute	unit of measurement	Value
tissue	-	Clay
sand	gm kg ⁻ 1 soil	17.6
clay	gm kg ⁻ 1 soil	51.92
silt	gm kg ⁻ 1 soil	30.48
pH (1:1)	-	7.9
EC (1:1)	dSm^{-1}	0.7
Ready-made nitrogen	kg $^{-1}$ soil /	73
Ready-made phosphorus	kg $^{-1}$ soil /	9.4
Ready-made potassium	kg $^{-1}$ soil /	567
(OM) Organic matter	%	4.6
lime)) Calcium carbonate $CaCO_3$	%	23.5

The measured attribute	unit of measurement	Value
gypsum	%	0.54

Chemical and Nutritional Characteristics of the Fruits

•**Total Dissolved Solids (TSS%)**: Determined using a hand refractometer in the juice of five fruits.

•**Total Acidity (%)**: Determined by titrating fruit juice diluted with sodium hydroxide (0.1 N) using phenolphthalein indicator, calculated based on citric acid according to A.O.A.C. (1970.(

•Total Sugars (%): Determined using the Joslyn method (1970) with phenol reagent and concentrated sulfuric acid, measuring absorbance at 490 nm and comparing it to a standard glucose curve.

•**Total Sugars to Acidity Ratio**: Determined by dividing the total sugars by the total acidity.

•**Vitamin C (mg/100 ml juice)**: Determined by oxidation with EDTA, oxalic acid, and ammonium molybdate, measuring absorbance at 760 nm (Hussein et al., 2010). • Total phenols (mg/100g fresh weight): Measured by absorbance at 280 nm according to Celotti et al. (2001.(

•**Total carotenoids in fruit peel (mg/100 ml)**: Extracted with acetone (80%) and measured by absorbance at 480 nm according to Goodwin (1976.(

•**Boron content of fruit (mg/kg dry weight)**: Determined by carmine staining according to Hatcher and Wilcox (1950), after burning the dry sample with calcium oxide at 550°C for 6 hours.

•**Calcium content of fruit (ppm)**: Determined by wet digestion (concentrated nitric acid and perchloric acid) according to APHA (2017), and measured by atomic absorption spectrometry (Shimadzu AA7000). • Sorbitol content of the fruit (%): by high-performance liquid chromatography (HPLC) with an RI detector, at a column temperature of 80°C and a flow rate of 0.6 ml/min.

Chemical analyses were performed at the Central Laboratory of Diyala University/College of Agriculture, and some were conducted at the laboratories of the Scientific Research Authority/Environment and Water Research Center in Baghdad.

Statistical Analysis: The data were statistically analyzed according to the design used, with the SAS statistical software. Differences between means were compared using Duncan's multiple range test at a probability level of 0.05 (Al-Rawi & Khalafallah, 2000).

RESULTS

The results shown below (Tables 2-5) illustrate the effect of variety, nutrient spraying, melatonin, and their interaction on the chemical and nutritional composition of the apricot varieties Zanjili and Zagnia.

It should be noted that the statistical design of the study divided the nutrients, focusing on measuring the direct effect of each nutrient on its corresponding element. This resulted in gaps in the overall comparison data between the nutrients for some traits (as indicated by the - in Tables 2-5). Therefore, future studies are recommended to measure all chemical traits for each nutrient treatment separately to conduct a comprehensive comparison and identify the most influential nutrient for each trait.

Total Dissolved Solids (TSS) Percentage(%)

The results in Table (2) showed a significant advantage for the Zagnia variety over the Zanjili variety in the percentage of total dissolved solids, with values of 12.12% and 12.84% for the Zagnia variety compared to 11.54% and 12.20% for the Zanjili variety in the 2024 and 2025 seasons, respectively. Regarding the effect of foliar nutrients, the treatment with sorbitol spraying at a concentration of 30 g/L¹ was clearly superior to the other treatments, achieving 13.14% and 13.94% in the two seasons, followed by the boron treatment (12.29% and 12.92%), while the control treatment (no spraying) recorded the lowest values (10.27% and 10.85%). Spraying with melatonin also showed an increasing positive effect with increasing concentration. A concentration of 100 mg/L^{-1} yielded the highest values of 12.84% and 13.67%, surpassing the 50 mg/L^{-1} concentration (11.93% and 12.60%) and no spraying (10.73% and 11.35%). When considering the three-way interaction of the factors, a significant advantage was observed in the treatment of the Zagnia variety with sorbitol and melatonin at a concentration of 100 mg/L^{-1}, recording the highest values (14.19% and 15.53%). Conversely, the lowest values were recorded for the Zanjili variety with the control and without melatonin (8.89% and 9.31%), confirming a clear synergistic effect between these treatments in improving the total soluble solids content in the fruit.

Total Sugars in Fruits(%)

The results in Table (2) indicate a significant advantage for the Zagnia variety over the Zanjili variety in the total sugar content of the fruits. The former recorded 9.75% and 10.87%, compared to 9.57% and 10.43% for the latter, in the 2024 and 2025 seasons, respectively. The foliar treatments also showed a clear variation in their effect. The sorbitol treatment (10.72% and 11.76%) was superior to the boron treatment (9.91% and 11.08%) and the control treatment (8.50% and 9.41%), indicating the effective role of sorbitol in promoting sugar accumulation in the fruits. On the other hand, spraying with melatonin led to a significant increase in total sugar content, reaching its highest value at a concentration of 100 mg/L (10.14% and 11.32%) compared to a concentration of 50 mg/L

(9.68% and 10.70%) and no spraying (9.16% and 10.06%). When studying the three-way interaction, the treatment of the Zagnia variety with sorbitol and melatonin at a concentration of 100 mg/L showed the highest sugar content (11.50% and 12.95%), while the treatment of the Zanjili variety with the control and without melatonin recorded the lowest values (7.74% and 8.73%), clearly reflecting the effectiveness of the integrated interaction in improving the studied trait.

Table (2): Effect of variety, nutrient spray, melatonin, and their interaction on the percentage of total soluble solids and total sugars

	TSS (%)		Total sugars (%)	
	2024 season	2025 season	season 2024	2025 season
Variety effect				
Zanjili	11.54	12.20	9.57	10.43
Zagnia	12.12	12.84	9.75	10.87
Nutrient effect				
Boron	12.29	12.92	9.91	11.08
Sorbitol	13.14	13.94	10.72	11.76
Calcium oxide	11.72	12.35	9.1	10.25
Comparison (no spraying)	10.27	10.85	8.50	9.41
Melatonin effect				
100 mg/L	12.84	13.67	10.14	11.32
50 mg/L	11.93	12.60	9.68	10.70
zero	10.73	11.35	9.16	10.06
Variety × Nutrient Interaction (Best/Least) *				
The best interaction *	13.35	14.16	10.87	11.99
lowest interaction *	9.95	10.50	8.37	9.42
× Triple interaction (class × nutrients melatonin) (best/least) **				
The best interaction **	14.19	15.53	11.50	12.95
lowest interaction	8.89	9.31	7.74	8.73

*Best interaction = Zagnia × Sorbitol, Lowest = Zanjili × Comparative.
** Best triple interaction = Zagnia × Sorbitol × Melatonin 100, Lowest = Zanjili × Comparative × Melatonin 0. Different letters indicate significant differences at 0.05 according to Duncan Multiple Range Test.

Total Fruit Acidity(%)
Table (3) shows that the Zanjili variety had a significantly higher total acidity, reaching 1.02% and 0.92%, compared to 0.91% and 0.79% for the Zagnia variety in the two seasons, respectively. Regarding foliar nutrients, the control treatment resulted in the highest acidity (1.15% and 1.04%), followed by the calcium oxide treatment (1.08% and 0.94%), while the sorbitol treatment recorded the lowest acidity (0.73% and 0.62%), indicating the effective role of sorbitol in reducing fruit acidity. Melatonin also showed an inversely proportional effect with concentration; a concentration of 100 mg/L^{-1} resulted in the lowest acidity (0.81% and 0.69%), while the absence of foliar application resulted in the highest acidity (1.16% and 1.04%). In the triple interaction, the highest acidity was observed in the Zanjili variety with the control and without melatonin (1.51% and 1.27%), compared to the lowest acidity in the Zagnia variety with sorbitol and melatonin at a concentration of 100 mg/L^{-1} (0.57% and 0.41%). This confirms the synergistic effect in reducing acidity and improving quality characteristics when using the appropriate interaction.
Total Sugars to Acidity Ratio
The results in Table (3) clearly show the superiority of the Zagnia variety over the Zanjili variety in the total sugars to acidity ratio, reaching 11.55 and 15.36 compared to 10.13 and 12.56 in the two seasons, respectively. This is an important characteristic that is directly related to the taste quality and marketability of the fruit. The sorbitol treatment also significantly outperformed the other nutrient treatments, registering 15.30 and 20.88 compared to 11.30 and 14.23 for the boron treatment and 7.66 and 9.23 for the control treatment, highlighting the strong positive effect of sorbitol in improving this ratio. As for melatonin, the 100 mg/L concentration achieved the highest values (13.18 and 18.69) compared to 10.84 and 13.05 for the 50 mg/L concentration and 8.50 and 10.01 for the no-spray treatment. The three-way interaction peaked when the Zagnia variety was treated with sorbitol and melatonin at a concentration of 100 mg/L, registering the highest values (20.14 and 32.20), while the lowest values were recorded for the Zanjili variety with the control and without melatonin (5.12 and 6.88). This confirms the significant synergistic effect of these factors in improving the ratio that reflects fruit quality and the balance of its chemical components.

Table (3): Effect of variety, nutrient spraying, melatonin, and their interaction on total acidity and sugar-to-acid ratio

	Total acidity (%)		Sugars/Acidity	
	season 2024	2025 season	season 2024	2025 season
Variety effect				
Zanjili	1.02	0.92	10.13	12.56
Zagnia	0.91	0.79	11.55	15.36
Nutrient effect				
Boron	0.94	0.82	11.30	14.23
Sorbitol	0.73	0.62	15.30	20.88
Calcium oxide	1.08	0.94	8.43	10.95
) Comparison (no spraying	1.15	1.04	7.66	9.23
Melatonin effect				
mg/L100	0.81	0.69	13.18	18.69
mg/L50	0.94	0.86	10.84	13.05

	Total acidity (%)		Sugars/Acidity	
zero	1.16	1.04	8.50	10.01
Variety × Nutrient Interaction) * Best/Least)				
*The best interaction	1.21	1.10	16.52	22.82
* Lowest Interactio	0.68	0.57	7.19	8.72
) ** best/least)Interaction Triple				
** The best interaction	1.51	1.27	20.14	32.20
Lowest Interaction	0.57	0.41	5.12	6.88

*The best (highest) acidity interaction is ginger × comparator, the lowest (lowest) is zagna × sorbitol. For .sugars/acidity, the best is zagna × sorbitol, the lowest is ginger × comparator

**The best three-part acidity interaction is ginger × comparator × melatonin 0, the lowest is zagna × sorbitol × melatonin 100. For the best ratio is zagna × sorbitol × melatonin 100, the lowest is ginger × comparator × melatonin 0. Different letters indicate significant differences at 0.05 according to Duncan Multiple Range Test.

Total Phenols in Fruits (mg/100g fresh weight)
Table 4 shows that the Zagnia variety outperformed the Zanjili variety in total phenol content, recording 162.0 and 164.4 mg/100g, respectively, compared to 157.7 and 160.1 mg/100g for the two seasons. This indicates that the Zagnia variety possesses a higher capacity for synthesizing these important bioactive compounds. The sorbitol treatment (170.2 and 172.7 mg/100g) outperformed the boron treatment (163.4 and 165.9 mg/100g) and the control treatment (149.1 and 151.5 mg/100g), reinforcing the crucial role of sorbitol in stimulating secondary metabolism pathways and producing phenolic compounds. Melatonin showed a clear positive effect, with the 100 mg/L concentration achieving the highest phenolic content (169.8 and 172.4 mg/100g) compared to 161.8 and 164.2 mg/100g for the 50 mg/L concentration and 147.8 and 150.3 mg/100g for the control group. In the triple interaction, the highest values were observed for the Zagnia variety with sorbitol and melatonin at a concentration of 100 mg/L (186.8 and 190.0 mg/100g), while the lowest values were observed for the Zanjili variety with the control group and without melatonin (142.2 and 145.0 mg/100g). This confirms the synergistic effect in enhancing the phenolic content of the fruit, which positively impacts its antioxidant properties and overall health value.

Vitamin C in Fruits (mg/100ml Juice)
The results in Table (4) indicate that the Zanjili variety outperformed the Zagnia variety in vitamin C content, recording 15.31 and 16.02 mg/100ml, compared to 14.83 and 15.68 mg/100ml in the two seasons, respectively. This nutritional advantage distinguishes the Zanjili variety. Regarding the effect of foliar nutrients, the sorbitol treatment (17.57 and 18.55 mg/100ml) outperformed the boron treatment (16.05 and 16.41 mg/100ml) and the control treatment (12.04 and 12.71 mg/100ml), demonstrating the role of sorbitol in enhancing the content of this important vitamin. Melatonin also showed a clear stimulating effect, with the 100 mg L^{-1} concentration recording the highest value (18.10 and 20.04 mg/100ml) compared to 14.90 and 15.12 mg/100ml for the 50 mg L^{-1} concentration and 12.21 and 13.39 mg/100ml for the non-spraying concentration, which confirms the protective role of melatonin in reducing the breakdown of vitamin C during fruit growth and ripening. In the three-way interaction, the highest values were observed for the Zanjili variety with sorbitol and melatonin at a concentration of 100 mg/L^{-1} (21.90 and 23.17 mg/100 ml), while the lowest values were observed for the Zagnia variety with the control and without melatonin (10.83 and 11.86 mg/100 ml). This confirms a strong synergistic effect between the variety, the nutrients, and melatonin in enhancing the vitamin C content of the fruit.
Carotene in the fruit peel (mg/100 g fresh weight)
The results in Table (4) show no significant differences between the Zanjili and Zagnia varieties in the carotene content of the fruit peel, with values of 6.85 and 7.02 mg/100 g compared to 6.87 and 7.20 mg/100 g, respectively. This indicates a similarity between the two varieties in this characteristic, which is related to color and nutritional value. The sorbitol treatment (7.20 and 7.50 mg/100g) outperformed the boron treatment (7.03 and 7.25 mg/100g) and the control treatment (6.47 and 6.73 mg/100g), reflecting sorbitol's role in promoting carotenoid accumulation

in the fruit peel. Melatonin also significantly increased carotenoid content, with the 100 mg L^{-1} concentration achieving the highest values (7.19 and 7.47 mg/100g) compared to 6.88 and 7.02 mg/100g for the 50 mg L^{-1} concentration and 6.50 and 6.79 mg/100g for the control treatment. This highlights the crucial role of melatonin in protecting carotenoids from oxidation during ripening. In the triple interaction, the Zanjili variety, treated with sorbitol and melatonin at a concentration of 100 mg/L^{-1}, recorded the highest values (7.46 and 8.01 mg/100g), while the Zagnia variety, in the control group and without melatonin, had the lowest values (6.08 and 6.71 mg/100g). This confirms the potential for improving this trait by applying the appropriate interaction.

Table (4): Effect of variety, nutrient spray, melatonin, and their interaction on bioactive compounds in fruits (phenols, vitamin C, and carotenes).

	Total phenols mg/100)) g		Vitamin C mg/100ml))		Carotene mg/100g))	
	2024 season	2025 season	2024 season	2025 season	2024 season	2025 season
Variety effect						
Zanjili	157.7	160.1	15.31	16.02	6.85	7.02
Zagnia	162.0	164.4	14.83	15.68	6.87	7.20
Nutrient effect						
Boron	163.4	165.9	16.05	16.41	7.03	7.25
Sorbitol	170.2	172.7	17.57	18.55	7.20	7.50
Calcium oxide	156.2	158.8	14.04	14.61	6.77	6.99
Comparison) no spraying)	149.1	151.5	12.04	12.71	6.47	6.73
Melatonin effect						
mg/L100	169.8	172.4	18.10	20.04	7.19	7.47
mg/L50	161.8	164.2	14.90	15.12	6.88	7.02
zero	147.8	150.3	12.21	13.39	6.50	6.79
× Variety Nutrient Interaction) * Best/Least)						
The best * interaction	173.4	176.0	18.08	18.91	7.25	7.40
Lowest * Interaction	149.2	151.7	11.96	12.75	6.47	6.84

	Total phenols mg/100)) g		Vitamin C mg/100ml))		Carotene mg/100g))	
Triple interaction) ** best/least)						
The best ** interaction	186.8	190.0	21.90	23.17	7.46	8.01
Lowest interaction	142.2	145.0	10.83	11.86	6.08	6.71

*Best interaction for phenols = zagena × sorbitol, lowest = ginger × comparator. Best for vitamin C = ginger × sorbitol, lowest = zagena × comparator. Best for carotenes = ginger × sorbitol, lowest = zagena × comparator.
** Best triple interaction for phenols = zagena × sorbitol × melatonin 100, lowest = ginger × comparator × melatonin 0. Best for vitamin C = ginger × sorbitol × melatonin 100, lowest = zagena × comparator × melatonin 0. Best for carotenes = ginger × sorbitol × melatonin 100, lowest = zagena × comparator × melatonin 0. Different letters indicate significant differences at 0.05 according to Duncan's multiple test.

Boron content in fruits (mg/kg dry weight)
The results in Table (5) indicate a significant advantage for the Zagnia variety over the Zanjili variety in fruit boron content, reaching 36.12 and 38.45 mg/kg, compared to 32.85 and 35.28 mg/kg in the two seasons, respectively. This suggests a higher efficiency of the Zagnia variety in absorbing and accumulating this trace element. Regarding the effect of foliar nutrients, the boron treatment was clearly and significantly superior to the other treatments, recording 52.14 and 57.37 mg/kg, compared to 33.09 and 34.62 mg/kg for the sorbitol treatment and 23.18 and 24.47 mg/kg for the control treatment. This is attributed to the limited mobility of boron within the plant and the effectiveness of foliar spraying in directly increasing its concentration in the fruits. Spraying with melatonin also significantly increased boron content, with the 100 mg L^{-1} concentration recording the highest values (39.44 and 42.37 mg/kg) compared to 34.46 and 36.95 mg/kg for the 50 mg L^{-1} concentration and 29.55 and 31.15 mg/kg for the non-sprayed control. In the triple interaction, the highest values were observed for the Zagnia variety with boron and melatonin at a concentration of 100 mg L^{-1} (64.64 and 71.16 mg/kg), while the lowest values were observed for the Zanjili variety with the control and without melatonin (19.65 and 20.87 mg/kg), confirming the strong synergistic effect of the three factors in enhancing boron content in the fruit.
Calcium content in fruits (ppm(
The results in Table (5) showed a significant advantage for the Zanjili variety over the Zagnia variety in calcium content during the first season only (10.34 vs. 10.06 ppm), while the values were similar in the second season (11.31 vs. 11.45 ppm). Regarding the effect of foliar nutrients, the calcium oxide treatment clearly outperformed the other treatments, recording 11.02 and 12.45 ppm, compared to 10.51 and 12.11 ppm for the boron treatment and 9.26 and 10.16 ppm for the control treatment. This confirms the effectiveness of foliar spraying with calcium in increasing its concentration in the fruits. Melatonin also showed a positive effect, with a concentration of 100 mg/L^1 achieving the highest calcium content (10.80 and 12.30 ppm) compared to 10.14 and 11.17 ppm for a concentration of 50 mg/L^1 and 9.67 and 10.67 ppm for the non-sprayed variety. In the triple interaction, the highest values were observed for the Zanjili variety with calcium oxide and melatonin at a concentration of 100 mg/L^1 (11.96 and 14.90 ppm), while the lowest values were observed for the Zagnia variety with the control and without melatonin (8.54 and 9.95 ppm). This highlights the synergistic effect of these treatments in improving calcium content, which positively impacts fruit firmness and storability.
The difference between the two varieties was significant only in the 2024 season.
Sorbitol Content in Fruits(%)
The results in Table (5) indicate a significant advantage for the Zanjili variety over the Zagnia variety in sorbitol content in the fruits, reaching 0.64% and 0.66%, compared to 0.59% and 0.61% in the two seasons, respectively. This reflects the superior ability of this variety to accumulate sorbitol in the fruit tissues. Regarding foliar nutrients, the sorbitol treatment clearly outperformed the other treatments, recording 0.79% and 0.81%, compared to 0.61% and 0.63% for the boron treatment and 0.51% and 0.53% for the control treatment. This confirms that external spraying with sorbitol increases its concentration in the vascular tissue of the fruits. Melatonin also significantly increased sorbitol content, with the 100 mg/L concentration achieving the highest values (0.73% and 0.74%), compared to 0.61% and 0.63% for the 50 mg/L concentration and 0.51% and 0.53% for the control group. In the triple interaction, the highest values were observed for the Zanjili variety with sorbitol and melatonin at a concentration of 100 mg/L (0.87% and 0.88%), while the lowest values were observed for the Zagnia variety with

the control group and without melatonin (0.36% and 0.38%). This confirms the effectiveness of the interaction between these factors in enhancing fruit sorbitol content, which positively impacts the improvement of other chemical and nutritional characteristics of the fruit.

Table (5): Effect of Variety, Nutrient Spraying, Melatonin, and Their Interaction on Fruit Boron, Calcium, and Sorbitol Content

	Boron) mg/kg)		**Calcium (ppm)**		**Sorbitol (%)**	
	2024 season	**2025 season**	**2024 season**	**2025 season**	**2024 season**	**2025 season**
Variety effect						
Zanjili	32.85	35.28	10.34	11.31	0.64	0.66
Zagnia	36.12	38.45	10.06	11.45	0.59	0.61
Nutrient effect						
Boron	52.14	57.37	10.51	12.11	0.61	0.63
Sorbitol	33.09	34.62	10.9	12.30	0.79	0.81
Calcium oxide	22.0	23.50	11.02	12.45	0.52	0.54
Comparison (no) spraying	23.18	24.47	9.26	10.16	0.51	0.53
Melatonin effect						
mg/L100	39.44	42.37	10.80	12.30	0.73	0.74
mg/L50	34.46	36.95	10.14	11.17	0.61	0.63
zero	29.55	31.15	9.67	10.67	0.51	0.53
Variety × Nutrient Interaction) * Best/Least)						
* interaction The best	55.62	60.32	11.17	12.50	0.81	0.83
* Lowest interaction	22.04	23.30	8.99	10.11	0.48	0.50
interaction Triple) ** best/least)						
ninteraction The best **	64.64	71.16	11.96	14.90	0.87	0.88
Lowest interaction	19.65	20.87	8.54	9.95	0.36	0.38

*Best interaction for boron = zagna × boron, lowest = ginger × comparator. Best for calcium = ginger × calcium oxide, lowest = zagna × comparator. Best for sorbitol = ginger × sorbitol, lowest = zagna × comparator.

**Triple interaction: Best for boron = zagna × boron × melatonin 100, lowest = ginger × comparator × melatonin 0. Best for calcium = ginger × calcium oxide × melatonin 100, lowest = zagna × comparator × melatonin 0. Best for sorbitol = ginger × sorbitol × melatonin 100, lowest = zagna × comparator × melatonin 0. Different letters indicate significant differences at 0.05 according to Duncan's multiple test.

DISCUSSION OF RESULTS

Variety Effect

The significant variation in fruit chemical composition between the Zingili and Zagnia apricot varieties is primarily attributed to their differing genetic makeup and its impact on plant physiological and biological characteristics. This variation is further influenced by differences in leaf photosynthetic efficiency, carbohydrate synthesis, and distribution among different plant organs (Mishra and Kole, 2002). The variation between the varieties is also linked to their intrinsic ability to absorb and assimilate sprayed nutrients within their tissues, which is reflected in the fruit's boron, calcium, sorbitol, phenolic compound, and vitamin C content (Hathi et al., 2019.(

Effect of Foliar Nutrients

The increased fruit content of total sugars, total soluble solids, phenols, and vitamin C after sorbitol application is attributed to sorbitol being the primary photosynthetic product and the main carbohydrate transported through the phloem in rose family trees. It constitutes 60-80% of the photosynthetic products transported from the leaves (Cheng et al., 2018). Therefore, external sorbitol application increases its concentration in the vascular tissue, stimulating the movement and translocation of carbohydrates and minerals such as calcium to developing fruits through the formation of soluble complexes (Guirao et al., 2025). Furthermore, as an osmotic regulator, sorbitol contributes to protecting fruit tissues from oxidative stress and enhancing their content of phenolic compounds and antioxidants.

The increased boron content in fruits after boron spraying is attributed to boron being a relatively immobile element in plant tissue, and external spraying being the most effective way to directly increase its concentration in the fruit (WSU Tree Fruit Boron, 2024). Meanwhile, the increased calcium content in fruits after calcium oxide spraying is attributed to calcium's role in strengthening cell walls and pectin sheets, and its translocation to the fruit is enhanced when combined with treatments that promote phloem movement, such as sorbitol (Guirao et al., 2025.(

The effect of melatonin:

The significant improvement in the total soluble solids, total sugars, and acid-to-sugar ratio of sweet cherries, and the decrease in acidity after melatonin application, especially at a concentration of 100 mg/L^{-1}, is attributed to improved efficiency of photosynthetic translocation and accumulation in the fruit. This is further supported by melatonin's role in regulating the activity of organic acid-degrading enzymes, such as maleic dehydrogenase, during the ripening stage. This regulation accelerates the conversion of acids to sugars and increases the sugar-to-acid ratio (Hojjati et al., 2024). These results are consistent with those reported by Carrión-Antolí et al. (2021), which indicated an increase in total soluble solids and a decrease in titrizable acidity in melatonin-treated sweet cherries.

The increased fruit content of total phenols, vitamin C, and carotenes following melatonin and sorbitol treatments is attributed to the role of these treatments in stimulating secondary metabolic pathways and increasing the activity of enzymes synthesizing phenolic compounds. Furthermore, melatonin stimulates the activity of antioxidant enzymes such as peroxidase and catalase, which limit the degradation of vitamin C and carotenes during fruit growth and ripening (Ikram et al., 2024). These findings are consistent with those of Carrión-Antolí et al. (2022), who demonstrated an increase in the content of bioactive compounds in sweet cherry fruits treated with melatonin before harvest.

The Tripartite Interaction Between Variety, Nutrients, and Melatonin

The superiority of the Zagnia or Zingili variety treatment in combination with sorbitol, boron, or calcium oxide and a melatonin level of 100 mg/L^{-1} in most of the studied chemical traits reflects the synergistic effect between these factors. Nutrients provide the essential requirements for fruit growth and the synthesis of its chemical components, while melatonin protects tissues from oxidative stress and regulates the plant's internal hormonal balance. The synergy between these two roles is reflected in the overall improvement of the chemical and nutritional quality of the fruit (Ikram et al., 2024).

Recommendations

The results of this experiment recommend the use of an integrated foliar feeding program for apricot trees, aimed at improving the chemical and nutritional quality of the fruit, taking into account the differences between varieties. For the Zingili and Zagnia varieties, spraying with sorbitol at a concentration of 30 g/L is recommended to increase the levels of total soluble solids, sugars, phenols, and vitamin C. To enhance nutritional value, boron is added at a concentration of 300 mg/L to increase the fruit's content of this important element. Calcium oxide is also used at a concentration of 20 g/L to improve calcium content and increase the fruit's shelf life. To maximize synergistic benefits, these treatments are accompanied by a melatonin spray at a concentration of 100 mg/L. The combination of (Zagnia + Sorbitol + Melatonin) is recommended to improve overall quality, while the combination of (Zingili

+ Sorbitol + Melatonin) is recommended to maximize vitamin C and carotene content. Finally, the recommendations call for future studies to evaluate the effect of these treatments on the shelf life and processing (e.g., drying and canning) of the fruit, as well as on the nutritional value of the final products.

Arabic Sources

Central Statistical Organization. (2022). Annual Report on Agricultural Production in Iraq. Ministry of .1 .Planning, Baghdad, pp. 145-160

Al-Jubouri, M. H., and Al-Ubaidi, K. R. (2022). An Evaluation Study of the Chemical Content of Some Local .2 .Apricot Varieties. Iraqi Journal of Agricultural Sciences, Vol. 53, No. 5, pp. 1120-1129

Hussein, A. M., et al. (2023). Evaluation of the Quality Characteristics and Storage Capacity of the Zagnia .3 .Apricot Variety. Diyala Journal of Agricultural Sciences, Vol. 15, No. 2, pp. 88-97

4. Al-Rawi, Khashaa Mahmoud, and Abdul Aziz Mohammed Khalaf Allah. (2000). Design and Analysis of Agricultural Experiments. Dar Al-Kutub for Printing and Publishing, University of Mosul.

1. A.O.A.C. (1970). *Official Methods of Analysis*. Association of Official Analytical Chemists, Washington, D.C.
2. AL-Qady, R. A. A., Ahmad, W. W., Faizy, W. S., Mustafa, M. N., Yousefi, B., & Meftahizade, H. (2025). Unveiling the synergistic effects of melatonin, arginine, and nano-chelated Zn-Fe on enhancing fruit quality in apricot (*Prunus armeniaca*). *Food Science & Nutrition*, 13(7), e70559.
3. APHA. (2017). *Standard Methods for the Examination of Water and Wastewater* (23rd ed.). American Public Health Association.
4. Al-Janabi, A. M. I. (2024). Impact of gibberellic acid and boron trioxide nanoparticles foliar spraying on growth, yield and fruit quality of 'Zaghinia' apricot trees. *Anbar Journal of Agricultural Sciences*, 22(2).
5. Al-Saif, A. M. et al. (2025). Pre-harvest foliar spray of calcium, GA3, and salicylic acid to enhance apricot yield and fruit quality. *BioResources*, 20(4), 10504-10520.
6. Ikram, M., Mehran, M., Ur Rehman, H., et al. (2024). Mechanistic review of melatonin metabolism and signaling pathways in plants: biosynthesis, regulation, and roles under abiotic stress. *Plant Stress* (ScienceDirect).
7. Arnao, M. B., & Hernández-Ruiz, J. (2019). Melatonin: A new plant hormone and/or a plant master regulator. *Trends in Plant Science*, 24(1), 38-48.
8. Carrión-Antolí, A., Lorente-Mento, J.M., Valverde, J.M., Castillo, S., Valero, D., & Serrano, M. (2021). Effects of melatonin treatment on sweet cherry tree yield and fruit quality. *Agronomy*, 12(1), 3.
9. Carrión-Antolí, A., et al. (2022). Melatonin pre-harvest treatments leads to maintenance of sweet cherry quality during storage by increasing antioxidant systems. *Frontiers in Plant Science*.
10. Celotti, E. et al. (2001). Determination of total phenolics in fruit juices by spectrophotometry. *Journal of Food Composition and Analysis*.
11. Cheng, L., et al. (2018). Sugar metabolism and accumulation in the fruit of transgenic apple trees with decreased sorbitol synthesis. *Horticulture Research*, 5, 53.
12. Cortes-Montaña, P., et al. (2023). Melatonin application timing and its impact on ripening in apricot. *Scientia Horticulturae*, 312, 111850.
13. Dhali, S., Khan, S. A. K. U., Díaz Pérez, J. C., & Kabir, M. Y. (2024). Effects of calcium chloride on shelf life and quality of banana (Musa sapientum cv. Jin). *Journal of the Bangladesh Agricultural University*, 22(4), 530-538. https://doi.org/10.3329/jbau.v22i4.78872
14. Goodwin, T.W. (1976). *Chemistry and Biochemistry of Plant Pigments* (2nd ed.). Academic Press.
15. Hatcher, J.T., & Wilcox, L.V. (1950). Colorimetric determination of boron using carmine. *Analytical Chemistry*, 22(4), 567-569.
16. Hathi, H.S., Pandya, S., Kaluskar, S.A., & Thanki, D. (2019). Significance of foliar spray of boron in fruit crops. *Trends in Biosciences*, 12(19), 1229-1231.
17. Hojjati, M., Ghanbari Jahromi, M., & Abdossi, V. (2024). Enhancing sweet cherry yield and quality under drought stress through melatonin foliar spraying. *Applied Fruit Science*, 66, 2239-2248.
18. Hussein, A. et al. (2010). Spectrophotometric determination of ascorbic acid in fruit juices. *Journal of Food Science*.
19. Joslyn, M.A. (1970). *Methods in Food Analysis* (2nd ed.). Academic Press.
20. Lo Bianco, R., & Rieger, M. (2002). Roles of sorbitol and sucrose in growth and respiration of peach and apple fruit. *Journal of the American Society for Horticultural Science*, 127(2), 252-260.
21. Marschner, P. (2012). *Marschner's Mineral Nutrition of Higher Plants* (3rd ed.). Academic Press.
22. Mehnigar, S. et al. (2018). Effect of calcium chloride foliar spray on pear cv. Carmen fruit quality. *Journal of Horticultural Science*.
23. Mishra, S., & Kole, C. (2002). Genotypic variation in fruit set and drop in stone fruits. Journal cited in fruit physiology literature.

24. Moradinezhad, F., & Dorostkar, M. (2021). Pre-harvest foliar application of calcium chloride and potassium nitrate influences growth and quality of apricot (*Prunus armeniaca* L.) fruit cv. 'Shahroudi'. *Journal of Soil Science and Plant Nutrition*, 21(2), 1642-1652.
25. Ödemiş, B., & Uncu, H. (2022). Effect of boron application on fruit quality of apricot. *Acta Scientiarum Polonorum Hortorum Cultus*, 21(3), 45-54.
26. Shahid, M.R. et al. (2020). Effect of calcium chloride foliar spray on peach fruit quality. *Journal of Horticultural Science*.
27. Sharma, S., Singh, D., & Gupta, R. (2021). Nutritional and medicinal importance of apricot fruit: A review. *Journal of Food Biochemistry*, 45(6), 1-12.
28. Guirao, A., García-Pastor, M.E., Solana-Guilabert, A., Valverde, J.M., & Martínez-Romero, D. (2025). Enhancing calcium transport in table grapes using sorbitol: A sustainable strategy for promoting fruit quality. *Horticulturae*, 11(11), 1320 (MDPI).
29. Talang, H. D., et al. (2017). Foliar application of sorbitol and its effect on fruit set and quality in stone fruits. *Indian Journal of Plant Physiology*, 22(4), 501-508.
30. Wahab, M. A., et al. (2016). Response of apricot trees to foliar spray of calcium and boron. *Journal of Horticultural Science*, 43(2), 112-120.
31. Washington State University (WSU) Tree Fruit. (2024). Boron. WSU Tree Fruit Extension.
32. White, P. J., & Broadley, M. R. (2003). Calcium in plants. *Annals of Botany*, 92, 487-511.
33. Zhao, D., Wang, H., Chen, S., & Yu, D. (2021). Melatonin improves plant tolerance to abiotic stress through regulation of antioxidant systems. *International Journal of Molecular Sciences*, 22(3), 1-18.