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Effect of Spraying Boron and Chelated Zinc on Some Chemical Characteristics of Three Date Palms

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Abstract

Date palm is one of the most important fruits due to it contains of minerals and vitamins thus the addition of nutrients such as boron and chelated zinc can improve fruit quality. To investigate the effect of zinc (Zn) and boron (B) on fruit quality, the Zn and B were spraying in chelated form. The treatments were applied at two stages: one week before, and one week after pollination with the 'Simsimi' male cultivar in 2025. The experiment included 12 treatments resulting from the interaction of two factors: the first factor being three female varieties (Zhadi, Khistawi, and Tabarzel), and the second factor being a combination of boron and chelated zinc (control, boron 1.5 mg L^{-1}, chelated zinc 50 mg L^{-1}, boron 1.5 mg L^{-1} + chelated zinc 50 mg L^{-1}). Spraying was conducted twice during the growing season. The experiment was carried out in factorial experiment with three replications. The study concludes that the use of a combined foliar spray of boron and chelated zinc is significantly increased total sugars and chlorophyll around 83.25% and 15.67% respectively. The Zhadi variety outperforms by giving the highest percentage of reduced sugars (65.38%) while the Khistawi variety was significantly superior in all the other characteristics. The results showed that spraying with zinc significantly affected on leaves content of chlorophyll and fruit content of nitrogen. The non-reduced sugar increased when spraying boron in khistawi. The combination of zinc and boron resulted in increasing protein, reduced and non-reduced sugar, and potassium in the fruits.

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Introduction

The date palm, which is a member of the Arecaceae family, is scientifically referred to as *Phoenix dactyliferous* L. It is a perennial fruit tree. Iraq is believed to be the oldest native home of this tree in the world, with over 600 varieties cultivated there. The date palm is one of the most important genera of this family it is afforded a distinct position, (Alam, 2023). The date palm considered as one of the oldest fruits in the world, and the essential reason for planting palm tree is their fruit which is rich of nutrients and bioactive compound such as phenolics, flavonoids and carotenoids. The palm date tree has many important commercial cultivars such as Zhadi, Khstawi and Tibarzal, which considered as the one of the most common cultivars in middle and south of Iraq. Regarding to the cultivars production Zhadi is the highest one among the others followed by Khastawi and Tibarzal (Al-Bakr 1972). These provide the human body with energy and work as antibiotic against several diseases (Younas *et al.,* 2020). The cultivation of the date palm occurs in a broad range of latitudes, specifically from latitudes 10° to 30° north of the equator, and it extends as

far as latitude 20° south of the equator. Its carbohydrates, proteins, alkaloids, flavonoids, potassium, calcium, magnesium, and phosphorus make it useful for both nutrition and medicine (Abdul Qadir *et al.,* 2020). Iraq has 22 million date palms, in accordance to the Central Statistical Organization (2024). Iraq produces 800,000 tons of date palms, and each tree produces 70kg.

Boron is an important part of both the growth and fruit quality of plants, applying boron improves crop productivity and quality, also facilitating sugar translocation across cell membranes, which moves sugars from where they are synthesized to where they are consumed or grown (Davarpanah *et al.,* 2016). According to Al-hajjaj (2018) boron has a significant effect on palm date fruit quality such as increasing flash and fruit weight, because of the important function it serves in creation of enzymes, as well as its involvement in the development of a variety of proteins and nucleic acids. Zinc is an important micronutrient for plants. Furthermore, it is responsible for the execution of a critical function in the processes of oxidation and reduction that take place in plants (Nandal and Solanki, 2021). Another important molecule, involved in controlling plant development and activating certain enzyme pathways, is indole-3-acetic acid, which has its synthesis modulated by this compound. Zinc is a vital element in several physiological functions and the insufficient of Zn will effect on fruit physiochemical characteristics. The other important rules of zinc are that it has physiological significance in date palm such as construction of chlorophyll, photosynthesis, and building of proteins (Rudani *et al.,* 2018). There is a lack of research about using boron and zinc on date palm cultivars, thus, this paper aim was to find the best concentrations of these two elements and its impact on the fruit quality in three date palm cultivars, as a result of the fact that date palms hold a great deal of importance was the key to start this research.

Materials and Methods

A field experiment was conducted in the orchard of the College of Agriculture, University of Diyala from 15th of March to 1st of October 2025 growing season to determine the effect of spraying *Boron and Chelated Zinc* (Boric acid 17% B, Zinc chelate 40% Zn) on three 10-year-old date palm (*Phoenix dactyliferous* L.) varieties; Zhadi, Khistawi, and Tabarzel, propagated vegetative by offshoots, and their effect on some chemical properties of the fruits.

Homogeneous trees as much as possible, free from disease infections, and irrigated by drip were selected. Three female date palms of each variety, each containing four clusters, were chosen, and the clusters were considered experimental units. Then, some physical and chemical properties of the orchard soil were analyzed before conducting the experiment (Table 1), with samples taken at a depth of 30-60 cm. Standard horticultural practices were carried out as needed.

The trees were pollinated with the male pollinator variety (Simsimi) on 1/4/2025, while the fruit harvesting process began on 1/10/2025. The fruit samples were taken at the maturity stage for the study analysis, while the leaf samples were taken at the mid-stage of the leaf from the fronds on 28/8/2025. The experiment included 12 treatments (tree) each treatment has four replicates (resulting from the interaction of two factors: the first being the female varieties (Zhadi, Khistawi, and Tabarzel), and the second being spraying with a combination of boron (Boric Acid H_3BO_3) and chelated zinc (Control, Boron at 1.5 mg L^{-1}, Chelated Zinc at 50 mg L^{-1}, and Boron 1.5 mg L^{-1} + Chelated Zinc 50 mg L^{-1}.

The spraying was conducted twice during the growing season surface-active agent (15 cm^{-3}.100 L^{-1} liquid soap), one week before and after pollination. One letter of the solution was used to each fruit cluster.

Table 1. Properties of orchard soil

Material	Unit	Material	Unit
Electrical conductivity (EC)	7.20 ds m^{-1}	pH	7.10
Organic matter	1.12 %	Cation exchange capacity (CEC)	17.2 cmolc kg^{-1}
Available nitrogen	54 mg kg^{-1}	Available phosphorus	8.9 mg kg^{-1}
Available potassium	134 mg kg^{-1}	Available zinc	0.65 mg kg^{-1}
Magnesium ion (Mg^{+})	290 mg kg^{-1}	Sulfate ion (SO_4^{-})	1365 mg kg^{-1}
Calcium carbonate ($CaCO_3$)	29.3 %	Clay	36.7 %
Loam	40.5 %	Sand	22.8 %
Soil texture	Clay Loam		

Vegetative Growth Measurements

Leaf Chlorophyll Content (%)

The chlorophyll content in leaf tissue was determined using SPAD (Withers *et al.,* 1978).

Yield and Fruit Quality Measurements

At harvest maturity, a composite sample of 25 samples was randomly collected from each experimental replicate for subsequent physical and chemical analyses (Al-Dulaimi and Homed, 2025).

Fruit Protein Content (%)

The total protein content in the fruit pulp was calculated based on the nitrogen concentration, using the standard conversion factor of 6.25 (Protein % = Nitrogen % × 6.25), (Belitz *et al.,* 2009).

Fruit Sugar Content (%)

Total sugars and reducing sugars were quantified according to the method as described by AOAC (2000); Lakho *et al.,* 2017).

Total sugar

To determine the total sugar content of date, 100 milliliters (ml) of the filtered sample from the solution were transferred into a conical flask, then 10 ml of 8.6% HCl (8.6 ml HCI was taken, mixed with a small volume of water, and then added to the final volume of 100 ml with distilled water) was added. After boiling the mixture for five minutes, it was allowed to cool before being neutralized with NaOH, by using three to four drops of phenolphthalein indicator. NaOH was added drop by drop until the mixture turned pink. The mixture was poured into a volumetric flask and filled with 250 ml of distilled water. After being moved to a burette, the mixture was titrated against a 10 ml Felhing's solution that contained four to five drops of methylene blue indicator until a brick-red hue emerged. The following formula was used to calculate the amount of solution used:

$$\text{Total sugar (\%)} = \frac{\text{Factor (4.95)} \times \text{dilution (250)}}{\text{Titre} \times \text{Sample weight} \times 10}$$

Reducing sugar

Ten grams of the date sample and one hundred milliliters of warm water were combined in a beaker. The soluble material was dissolved by stirring the mixture. After passing through Whatman filter paper No. 4, distilled water was added to get the final volume of 250 ml. After being moved to a burette, the solution was titrated against a 10 ml Fehling's solution in a conical flask with four to five drops of methylene blue indicator until a brick-red hue emerged. After noting the burette reading, the following formula was used to calculate the result:

$$\text{Reducing sugar (\%)} = \frac{\text{Factor (4.95)} \times \text{dilution (250)} \times 2.5}{\text{Titre} \times \text{Sample weight} \times 10}$$

Non-reducing sugar

Non-reducing sugar was estimated by difference using following formula:

Non-reducing sugar (%) = Total sugar (%) – reducing sugar (%)

Leaf Nitrogen Percentage (%)

The nitrogen concentration in leaf tissue was determined using the Micro-Kjeldahl digestion and distillation method. Briefly, a 10 ml aliquot of the digested sample was distilled with 10 ml of 40% sodium hydroxide. The liberated ammonia was trapped in a boric acid solution and titrated with 0.1 N hydrochloric acid to a faint pink endpoint (Belitz *et al.,* 2009). The nitrogen percentage was calculated using the following formula:

N (%) = (Atomic Weight of N × Volume of Digested Sample × Normality of Acid × Volume of Acid Consumed) / (1000 × Volume of Sample Aliquot × Weight of Original Sample) × 100

Fruit Phosphorus Percentage (%)

The phosphorus concentration in fruit samples was measured colorimetrically. The phosphomolybdate complex was developed and its absorbance was read at a wavelength of 410 nm using a spectrophotometer (Model 1100, V-Lab EMC), as per the method described by John (1970).

Fruit Potassium Percentage (%)

The potassium concentration in fruit samples was determined using flame photometry (Model 378, Elico), following the standard procedure outlined by John (1970).

Statistical analysis

The experiment was conducted using a completely randomized block design (RCBD) for a factorial experiment with three replications. The results were analyzed using SAS (2003) and the means were compared using Duncan's multiple range test at a significance level of 0.05.

Results and Discussion

Leaf Chlorophyll Content (%)

Table 2 shows the significantly superiority of the Khistawi variety over the other study varieties, as it gave the highest chlorophyll rate of 15.67%. In the spraying treatments, the zinc spraying treatment significantly outperformed the other spraying treatments, providing the highest

chlorophyll rate of 14.71%. In the interaction treatments, all Khistawi treatments (control, boron spraying, zinc spraying, and boron and zinc spraying) significantly outperformed the other compatible treatments in chlorophyll percentage, providing the highest rates of 15.64%, 15.69%, 15.67%, and 15.69% respectively, while the lowest rate was 12.64% in the combination treatment with Zhadi.

Table 2. Effect of Foliar Application of Boron and Chelated Zinc on the chlorophyll of Three Date Palm Cultivars

Date Palm Cultivars	Foliar spray				Mean effect of date palm cultivars
	Control	Boron (1.5 mg L^{-1})	Zinc (Zn) Spray (50 mg L^{-1})	Boron 1.5 mg L^{-1} + Chelated Zinc 50 mg L^{-1}	
Zhadi	13.58 f	13.02 h	13.48 g	12.64 i	13.18 c
Khistawi	15.64 a	15.67 a	15.69 a	15.69 a	15.67 a
Tabarzel	14.41 e	14.48 d	14.96 b	14.60 c	14.61 b
Mean effect of foliar spray	14.54 b	14.39 c	14.71 a	14.31 d	

*Values with distinct letters are significantly different from one another according to Duncan's multiple range test at the 0.05 probability level.
*Values that have the same letters are not significantly different from each other according to Duncan's polynomial test at 0.05. Probability level.

Fruit Protein Content (%)

The Khistawi cultivar significantly excelled in the protein percentage trait (table 3), achieving the highest percentage of 1.825%. In the spraying treatments, the combined zinc and boron spraying treatment yielded the highest percentage of 1.845%, surpassing the other spraying treatments significantly. In the interaction, the Zhadi variety with combined spraying and The Khistawi variety with combined spraying outperformed the other compatible treatments, achieving the highest percentages of 1.964% and 1.946% respectively, while the lowest percentages were control treatment with Tabarzel and Zhadi 1.484% and 1.481% respectively.

Table 3. Effect of Foliar Application of Boron and Chelated Zinc on the protein of Three Date Palm Cultivars

Date Palm Cultivars	Foliar spray				Mean effect of date palm cultivars
	Control	Boron (1.5 mg L^{-1})	Zinc (Zn) Spray (50 mg L^{-1})	Boron 1.5 mg L^{-1} + Chelated Zinc 50 mg L^{-1}	
Zhadi	1.481 f	1.819 bc	1.771 c	1.964 a	1.759 b
Khistawi	1.674 d	1.841 b	1.838 b	1.946 a	1.825 a
Tabarzel	1.484 f	1.615 e	1.606 e	1.624 e	1.582 c
Mean effect of foliar spray	1.546 c	1.758 b	1.738 b	1.845 a	

Fruit Sugar Content (%)

Table 4 illustrate total sugar characteristic, the Khistawi variety achieved the highest ratio at 83.25%, outperforming all the other types. When compared to the percentages obtained from the other spraying treatments, the combination of sprayed treatment with zinc and boron had the highest percentage rate of 79.42%. This rate was much greater than the others. When compared to the other authorized treatments, the Khistawi variety that was associated with spray demonstrated a higher percentage of effectiveness during the interaction, reaching a maximum rate of 85.87% and a lowest rate of 71.52% at Zhadi with control treatment.

Table 4. Effect of Foliar Application of Boron and Chelated Zinc on Total Sugar of Three Date Palm Cultivars

Date Palm Cultivars	Foliar spray				Mean effect of date palm cultivars
	Control	Boron (1.5 mg L^{-1})	Zinc (Zn) Spray (50 mg L^{-1})	Boron 1.5 mg L^{-1} + Chelated Zinc 50 mg L^{-1}	
Zhadi	71.52 l	73.57 j	73.13 k	74.76 i	73.24 c
Khistawi	79.85 d	85.38 b	81.92 c	85.87 a	83.25 a
Tabarzel	75.19 h	77.33 f	76.94 g	77.63 e	76.77 b
Mean effect of foliar spray	75.52 d	78.76 b	77.33 c	79.42 a	

Fruit Reducing Sugar (%)

Among all the varieties that were included in the study (Table 5), the Zhadi type was the most successful at reducing the amount of sugar that was present. The other varieties fell well behind it. The greatest percentage that was documented for this particular type was 65.38 percent. The boron spraying treatment demonstrated had a significantly greater level of effectiveness when it was compared with the other spraying processes. The therapy reached its highest efficacy rate, which was 62.82 percent. The greatest percentage recorded among the interaction treatments was 65.6%, which was achieved by the Zahidi cultivar that had been treated with boron. The lowest ratio observed 59.65% at Tebarzel treated with boron.

Table 5. Effect of Foliar Application of Boron and Chelated Zinc on Reduced Sugar of Three Date Palm Cultivars

Date Palm Cultivars	Foliar spray				Mean effect of date palm cultivars
	Control	Boron (1.5 mg L^{-1})	Zinc (Zn) Spray (50 mg L^{-1})	Boron 1.5 mg L^{-1} + Chelated Zinc 50 mg L^{-1}	
Zhadi	65.07 d	65.60 a	65.48 b	65.37 c	65.38 a
Khistawi	60.99 j	63.08 e	61.29 i	61.99 f	61.84 b
Tabarzel	61.93 g	59.78 k	61.57 h	59.65 l	60.73 c
Mean effect of foliar spray	62.66 c	62.82 a	62.78 b	62.34 d	

Fruit Non-Reducing Sugar (%)

In the non-reducing sugars characteristic as shown in Table 6, the Khistawi variety performed exceptionally well, yielding the highest values at 21.41%. At 17.07%, the combined spraying of zinc and boron produced the highest results among the spraying procedures, greatly outperforming the other spraying treatments. The Khistawi variety with the combining spray functioned better in the interaction than the other suitable treatments, yielding the greatest values at 23.85% and the lowest at 6.480% Zhadi with control treatment.

Table 6. Effect of Foliar Application of Boron and Chelated Zinc on Non-Reduced Sugar of Three Date Palm Cultivars

Date Palm Cultivars	Foliar spray				Mean effect of date palm cultivars
	Control	Boron (1.5 mg L^{-1})	Zinc (Zn) Spray (50 mg L^{-1})	Boron 1.5 mg L^{-1} + Chelated Zinc 50 mg L^{-1}	
Zhadi	6.480 l	7.996 j	7.685 k	9.420 i	7.89 c
Khistawi	18.88 d	22.27 b	20.64 c	23.85 a	21.41 a
Tabarzel	13.23 h	17.52 f	15.34 g	17.96 e	16.01 b
Mean effect of foliar spray	12.86 d	15.93 b	14.55 c	17.07 a	

Leaf Nitrogen Percentage (%)

Table 7 demonstrates the results for Khistawi variety performed significantly better than the other varieties in the study. It had a highest nitrogen content percentage, at 2.087%. The zinc spray treatment was by far the best of the spraying treatments, giving a highest nitrogen content percentage, at 2.046%. The Khistawi variety treated with the zinc spraying performed significantly better compared to all of the interaction treatments in terms of nitrogen percentage. It experienced a highest percentage of 2.136%, whereas the lowest ratio was 1.913% Zhadi with control treatment.

Table 7. Effect of Foliar Application of Boron and Chelated Zinc on Nitrogen content of Three Date Palm Cultivars

Date Palm Cultivars	Foliar spray				Mean effect of date palm cultivars
	Control	Boron (1.5 mg L^{-1})	Zinc (Zn) Spray (50 mg L^{-1})	Boron 1.5 mg L^{-1} + Chelated Zinc 50 mg L^{-1}	
Zhadi	1.913 f	1.923 e	1.916 f	1.918 ef	1.917 c
Khistawi	2.089 b	2.088 b	2.085 b	2.086 b	2.087 a
Tabarzel	2.007 c	1.987 d	2.136 a	1.991 d	2.030 b
Mean effect of foliar spray	2.00 b	1.99 c	2.046 a	1.99 c	

Fruit Phosphorus Percentage (%)

Table 8 demonstrates that the "Khistawi" variety performed significantly better than all other varieties in the study due to a highest phosphorous percentage, at 0.521%. In all of the spraying, the control treatments proved significantly more effective than the other applied treatments due to a highest phosphorous percentage at 0.424%. The Khistawi variety that received treatment with the control significantly exceeded all of the combination treatments in phosphorous levels, with a ratio 0.553%, whereas the rate with the lowest value was 0.303% Zhadi with Zinc spray.

Table 8. Effect of Foliar Application of Boron and Chelated Zinc on Phosphorus content of Three Date Palm Cultivars

Date Palm Cultivars	Foliar spray				Mean effect of date palm cultivars
	Control	Boron (1.5 mg L^{-1})	Zinc (Zn) Spray (50 mg L^{-1})	Boron 1.5 mg L^{-1} + Chelated Zinc 50 mg L^{-1}	
Zhadi	0.333 j	0.343 i	0.303 k	0.363 g	0.335 c
Khistawi	0.553 a	0.523 b	0.513 c	0.496 d	0.521 a
Tabarzel	0.386 f	0.356 h	0.406 e	0.306 k	0.364 b
Mean effect of foliar Spray	0.424 a	0.407 b	0.407 b	0.388 c	

Fruit Potassium Percentage (%)

Table 9 demonstrates the results for the "Khistawi" variety performed significantly better than all other varieties in the investigation, with a potassium percentage of 2.556%. The zinc and boron spraying treatment performed significantly more effectively than all of the applied spray treatments, exhibiting a highest potassium percentage of 2.513%.

In the combination of treatments, the Khistawi variety treated with the zinc and boron spraying experienced a highest potassium percentage, with an average rate of 3.046% and a percentage of 2.213%. It improved significantly compared to all the interaction treatment groups in Zhadi and control treatment.

Table 9. Effect of Foliar Application of Boron and Chelated Zinc on Potassium content of Three Date Palm Cultivars

Date Palm Cultivars	Foliar spray				Mean effect of date palm cultivars
	Control	Boron (1.5 mg L^{-1})	Zinc (Zn) Spray (50 mg L^{-1})	Boron 1.5 mg L^{-1} + Chelated Zinc 50 mg L^{-1}	
Zhadi	2.213 e	2.406 b	2.283 cd	2.243 de	2.286 b
Khistawi	2.403 b	2.383 b	2.393 b	3.046 a	2.556 a
Tabarzel	2.276 cd	2.306 c	2.296 c	2.250 cde	2.282 b
Mean effect of foliar spray	2.297 c	2.365 b	2.324 c	2.513 a	

The outcomes revealed that there were significant variances throughout all of the criteria that had been investigated. It is possible that the considerable discrepancies that exist between the different kinds with regard to the features that were examined are the result of variations in the genetic material of these varieties. This genetic material is subject to impact from a number of important components, including genes, hormones, and enzymes. These parameters have both a direct and an inverse relationship with each other, according to Mohammed (1985). The application of boron to date palms may significantly enhance the levels of nitrogen, phosphorus, and potassium, after pollination hence substantially increasing photosynthetic outputs. This results in an increased production of essential nutrients necessary for fruit development (Al-Khafaji, 2019). This may result from the crucial role of boron in numerous vital processes in plants, including the synthesis of proteins, lipids, and carbohydrates, as well as the activation of various enzymes, such as oxidase, which enhances photosynthetic efficiency and significantly influences growth traits, including leaf chlorophyll content (Omar *et al.,* 2014).

The procedure of boron spraying has significant implications on most of the characteristics that were studied. This is because boron is important for making proteins and hormones, especially indole-3-acetic acid (IAA), which makes cells and tissues grow and divide. It also makes it easier for carbohydrates to move around and makes the cell membrane more permeable (Rainham, 2001). Al-Sahhaf (1989) study found that it is simpler as well as faster to move polar sugars that have been mixed with boron than to move polar sugars on their own. This could be also because zinc helps activate the root system, which lets it take in nutrients and send them to the leaves. This, in turn, raises the amount of chlorophyll (Yadav, 2014). The findings can also be ascribed to the presence of boron and zinc, which are elements that enhance the sugar content in fruit (Ramezani and Shekafandeh, 2012). The results from the studies by Zaen El–Daen *et al.* (2017); Al-hajjaj (2018) align with the outcome of the current research; this study confirmed the results of the study conducted by Kiwan *et al.* (2018).

Conclusions

The results show that foliar application of chelated zinc and boron, individually and their interaction, improves biochemical attributes of date palm (*phoenix dactylifera.* L.). Significant, improvements in total sugar content, relative chlorophyll (SPAD), protein, total nitrogen, phosphorus, and potassium were recorded, especially, plants treated with combination of chelated zinc and boron. These outcomes indicate that chelated zinc and boron clearly affect physiological and chemical fruit quality. Zinc could be assisting activation the root system, which leads to take in nutrients and direct them to the leaves. Boron is essential for creation proteins and hormones, especially indole-3-acetic acid (IAA), that make tissues grow and divide. Hence, it can be recommended that the use of chelated zinc and boron improve the chemical characteristics according to the finding of the research results.

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Conflict of interest

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Author Contribution

A. T. Homed; Methodology and write the original draft, Preparation, M. D. Abdulhadi; Software, Data Curation, M. A. Hameed and M. T. Haraz review, editing, and finalize the manuscript. All authors read and agree to the submission of the manuscript to the journal.

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