

## Influence of Pollen Source, Pollination Time, and Chelated Zinc on Physical Characteristics of Date palm c.v. Barhee

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### Abstract

A field experiment was conducted during the 2025 growing season at Al-Amir Private Model Farm, Al-Harouniyah, Al-Muqdadiya District, Diyala Province, Iraq, to investigate the effects of pollen source, pollination time, and chelated zinc application on the growth and yield of tissue-cultured 'Barhee' date palm (*Phoenix dactylifera* L.) trees aged 13 years. The experiment was arranged as a factorial trial within a randomized complete block design (RCBD) with three factors: pollination time (24 and 72 h after spathe opening), pollen source (Khadrawi, Berban, and a mixture of Khadrawi + Berban pollen), and chelated zinc foliar application (0, 50, and 100 mg L<sup>-1</sup>). Eighteen treatment combinations were replicated three times.

The results showed that the mixed pollen source (Khadrawi + Berban) significantly improved fruit set (77.70%), fruit weight (12.29 g), flesh weight (11.47 g), fruit volume (11.47 cm<sup>3</sup>), and total yield (135.9 kg palm<sup>-1</sup>) compared with the other pollen sources. Pollination after 24 h produced superior values for fruit weight (12.08 g), flesh weight (11.29 g), and total yield (134.7 kg palm<sup>-1</sup>). Foliar application of chelated zinc at 100 mg L<sup>-1</sup> significantly increased fruit set (78.02%), fruit volume (11.66 cm<sup>3</sup>), and flesh-to-seed ratio (16.97), whereas 50 mg L<sup>-1</sup> resulted in the highest flesh weight (11.26 g). The three-way interaction among mixed pollen, pollination after 24 h, and 100 mg L<sup>-1</sup> chelated zinc produced the highest values for fruit set (83.34%), fruit weight (13.64 g), flesh weight (12.71 g), fruit volume (14.16 cm<sup>3</sup>), total yield (176.5 kg palm<sup>-1</sup>), and flesh-to-seed ratio (13.66). These findings indicate that combining mixed pollen (Khadrawi + Berban), pollination within 24 h, and foliar application of chelated zinc at 100 mg L<sup>-1</sup> can enhance fruit set, yield, and fruit quality of tissue-cultured 'Barhee' date palms.

**Keywords:** Date palm, Barhee cultivar, Pollination, Pollen source, Pollination timing, Chelated zinc

### Introduction

Date palm (*Phoenix dactylifera* L.) is an economically important fruit crop widely cultivated in tropical and subtropical regions. It plays a significant role in food security and agricultural sustainability due to its high nutritional value and increasing global demand [1]. Date fruits are rich in carbohydrates, dietary fiber, minerals, and bioactive compounds, which contribute to their nutritional

and health-promoting properties [2],[3]. Because date palm is a dioecious species, successful fruit production depends on effective pollination. The pollen source and pollination timing are critical factors influencing fruit set, yield, and fruit quality. Variations among male cultivars can affect fruit characteristics, including fruit size, weight, and chemical composition, making the selection of a suitable

pollinator essential for improving productivity [4], [5]. Chelating agents are widely used to enhance micronutrient availability and uptake by plants. Among these micronutrients, zinc (Zn) is essential for plant growth and development. Foliar application of chelated zinc is considered an effective practice for improving nutrient efficiency, particularly under conditions that limit nutrient availability in the soil [6]. Foliar fertilization has become an important management strategy in date palm cultivation, helping to overcome nutrient deficiencies and environmental constraints. Recent studies have shown that chelated zinc application can improve fruit physical and chemical attributes, including fruit size, weight, total soluble solids, sugar content, and fruit set percentage, ultimately contributing to enhanced yield and

Three pollen sources (Khadrawi, Berban, and a mixture of Khadrawi + Berban) and two pollination times (24 and 72 h after spathe opening) were applied, while chelated zinc was sprayed at 0, 50, and 100 mg L<sup>-1</sup> in three monthly applications starting from May 4, 2025. A surfactant was added to improve spray efficiency. Standard orchard practices, including pruning, weeding, and soil cultivation, were uniformly applied. Leaf samples were collected at the khalal stage, and fruit samples were harvested at tamar stage between October 10 and 30, 2025. Physical analyses were conducted at the University of Diyala, College of Agriculture, using standard laboratory methods.

### Studied Traits

- **Fruit set percentage (%)**: Determined by selecting 20 spathes per palm and calculating the proportion of set fruits relative to total potential fruit positions, including set fruits, shot berries, and flower scars according to [8].
- **Average fruit weight (g)**: Calculated by weighing 20 randomly selected fruits per

fruit quality [7]. This study aimed to evaluate the effects of pollination time, pollen source, and chelated zinc application on fruit set, yield, and fruit quality of 'Barhee' date palms.

### Materials and Methods

The field experiment was conducted during the 2025 growing season at Al-Amir Private Model Farm, Al-Harouniyah, Al-Muqdadiya District, Diyala Province, Iraq, to study the effects of pollen source, pollination time, and foliar application of chelated zinc on growth, yield, and fruit quality of 13-year-old date palms grown under drip irrigation conditions. Fifty-four uniform and healthy palms were selected and arranged in a randomized complete block design (RCBD) with three replications.

bunch at harvest and dividing the total weight by the number of fruits.

- **Fruit volume (cm<sup>3</sup>)**: Measured using the water displacement method by immersing 20 fruits in a graduated cylinder and recording the increase in water level [9]
- **Total yield (kg palm<sup>-1</sup>)**: Determined by weighing all harvested fruits per palm using a field balance and calculating the mean yield per treatment.
- **Average flesh weight (g)**: Estimated from 20 fruits by separating pulp from seeds and calculating the mean flesh weight per fruit.
- **Flesh-to-seed ratio**: Calculated by dividing the weight of the fruit flesh by the weight of the seed.

### Statistical Analysis

The experiment was conducted as a factorial arrangement within a randomized complete block design (RCBD) with three factors: pollination time (24 and 72 h after pollination), pollen source (Khadrawi, Berban, and a mixture of Khadrawi + Berban), and foliar application of chelated zinc (0, 50, and 100 mg L<sup>-1</sup>). This

resulted in 18 treatment combinations. Each treatment was replicated three times, and each palm represented an experimental unit, giving a total of 54 experimental units. Data were

## Results and Discussion

### Fruit set percentage

As shown in table (1), significant differences were observed among pollen sources and zinc treatments, while pollination time had no significant effect on fruit set percentage. The mixed pollen source (Khadrawi + Berban) recorded the highest fruit set (77.70%), whereas Berban pollen showed the lowest value (76.33%). Foliar application of chelated zinc at 100 mg L<sup>-1</sup> resulted in the highest fruit set (78.02%), while the control treatment recorded the lowest value (76.20%).

Regarding two-way interactions, the highest fruit set for pollen source × pollination time was recorded in mixed pollen (Khadrawi + Berban) with 24 h pollination (78.28%), whereas lowest was in Berban pollen with 24 h pollination

analyzed using SPSS software, and treatment means were compared using Duncan's multiple range test at a 0.05

(76.05%). For pollen source × zinc, the maximum value was obtained from mixed pollen + 100 mg L<sup>-1</sup> zinc (80.73%), while the minimum was recorded in Berban pollen + 100 mg L<sup>-1</sup> zinc (75.16%). In pollination time × zinc interaction, the highest fruit set was observed at 24 h pollination combined with 100 mg L<sup>-1</sup> zinc (78.66%), whereas lowest values were recorded in the control treatment under both pollination times (75.79% and 76.60%). The three-way interaction revealed that combination of mixed pollen (Khadrawi + Berban), pollination at 24 h, and 100 mg L<sup>-1</sup> zinc produced highest fruit set (83.34%), while lowest value was recorded in Berban pollen with 24 h pollination and 100 mg L<sup>-1</sup> zinc (74.31%).

**Table 1. Effects of pollen source, pollination time, and chelated zinc application on fruit set (%) of 'Barhee' date palm**

| Pollen source                    | Chelated zinc<br>mg L <sup>-1</sup> | Pollination time |           | Pollen source ×<br>chelated zinc |
|----------------------------------|-------------------------------------|------------------|-----------|----------------------------------|
|                                  |                                     | 24 h             | 72 h      |                                  |
| Khadrawi                         | 0                                   | 76.57 bcd        | 76.37 bcd | 76.47 bc                         |
|                                  | 50                                  | 76.60 bcd        | 78.22 b   | 77.41 b                          |
|                                  | 100                                 | 78.33 b          | 78.03 b   | 78.18 b                          |
| Berban                           | 0                                   | 76.28 bcd        | 77.55 bc  | 76.91 ab                         |
|                                  | 50                                  | 77.57 bc         | 76.23 bcd | 76.90 bc                         |
|                                  | 100                                 | 74.31 d          | 76.01 bcd | 75.16 c                          |
| Mixed<br>(Khadrawi +<br>Berban)  | 0                                   | 74.53 cd         | 75.88 bcd | 75.21 c                          |
|                                  | 50                                  | 76.95 bcd        | 77.36 bcd | 77.16 bc                         |
|                                  | 100                                 | 83.34 a          | 78.11 b   | 80.73 a                          |
| pollen source x Pollination time |                                     |                  |           | Mean pollen source               |
| Khadrawi                         |                                     | 77.17 ab         | 77.54 ab  | 77.35 AB                         |
| Berban                           |                                     | 76.05 b          | 76.60 ab  | 76.33 B                          |
| Mixed (Khadrawi + Berban)        |                                     | 78.28 a          | 77.12 ab  | 77.70 A                          |

| Chelated zinc x Pollination time |          |          | Mean Chelated zinc |
|----------------------------------|----------|----------|--------------------|
| 0                                | 75.79 b  | 76.60 b  | 76.20 B            |
| 50                               | 77.04 ab | 77.27 ab | 77.16 AB           |
| 100                              | 78.66 a  | 77.38 ab | 78.02 A            |
| Mean Pollination time            | 77.170 A | 77.09 A  |                    |

Means sharing the same letter are not significantly different at  $p \leq 0.05$  according to Duncan's test

### Average

Table (2) showed significant differences among pollen sources and pollination timing, while zinc application had no significant effect on average fruit weight. The mixed pollen source (Khadrawi + Berban) recorded the highest fruit weight (12.29 g), whereas Khadrawi pollen showed the lowest value (11.39 g). Pollination at 24 h resulted in higher fruit weight (12.08 g) compared with 72 h (11.57 g). For two-way interactions, highest fruit weight was recorded in the combination of mixed pollen and 24 h pollination (12.89 g), while lowest value occurred with Khadrawi pollen at 24 h (11.34 g). In pollen  $\times$  zinc interaction, the maximum value was observed in mixed pollen with 100 mg L<sup>-1</sup> zinc (12.77 g),

### fruit

whereas the minimum was recorded in Khadrawi pollen with 50 mg L<sup>-1</sup> zinc (11.17 g). For pollination time  $\times$  zinc interaction, highest fruit weight was obtained at 24 h combined with 50 and 100 mg L<sup>-1</sup> zinc (12.38 and 12.29 g, respectively), while the lowest value was recorded at 72 h with 50 mg L<sup>-1</sup> zinc (11.43 g). The three-way interaction showed that combination of mixed pollen (Khadrawi + Berban), pollination at 24 h, and foliar application of 50 and 100 mg L<sup>-1</sup> zinc produced highest fruit weights (13.57 and 13.64 g, respectively), whereas the lowest value was recorded in Berban pollen at 72 h with 100 mg L<sup>-1</sup> zinc (10.64 g).

### weight

**Table 2. Effects of pollen source, pollination time, and chelated zinc application on fruit weight (g) of 'Barhee' date palm.**

| Pollen source                    | Chelated zinc<br>mg L <sup>-1</sup> | Pollination time |            | Pollen source $\times$ chelated<br>zinc |
|----------------------------------|-------------------------------------|------------------|------------|-----------------------------------------|
|                                  |                                     | 24 h             | 72 h       |                                         |
| Khadrawi                         | 0                                   | 11.52 b-e        | 11.26 bcde | 11.39 cd                                |
|                                  | 50                                  | 11.46 b-e        | 10.89 de   | 11.17 d                                 |
|                                  | 100                                 | 11.04 cde        | 12.30 b    | 11.67 cd                                |
| Berban                           | 0                                   | 11.74 b-e        | 12.40 b    | 12.07 abc                               |
|                                  | 50                                  | 12.05 bc         | 11.63 bcde | 11.84 bcd                               |
|                                  | 100                                 | 12.25 bc         | 10.64 e    | 11.45 cd                                |
| Mixed<br>(Khadrawi +<br>Berban)  | 0                                   | 11.45 b-e        | 11.82 bcde | 11.64 cd                                |
|                                  | 50                                  | 13.57 a          | 11.39 bcde | 12.48 ab                                |
|                                  | 100                                 | 13.64 a          | 11.90 bcd  | 12.77 a                                 |
| pollen source x Pollination time |                                     |                  |            | Mean pollen source                      |
| Khadrawi                         |                                     | 11.34 c          | 11.45 bc   | 11.39 B                                 |
| Berban                           |                                     | 12.01 b          | 11.56 bc   | 11.78 AB                                |

|                                  |         |          |                    |
|----------------------------------|---------|----------|--------------------|
| Mixed (Khadrawi + Berban)        | 12.89 a | 11.70 bc | 12.29 A            |
| Chelated zinc x Pollination time |         |          | Mean Chelated zinc |
| 0                                | 11.57 b | 11.83 ab | 11.70 A            |
| 50                               | 12.38 a | 11.43 b  | 11.91 A            |
| 100                              | 12.29 a | 11.44 b  | 11.86 A            |
| Mean Pollination time            | 12.08 A | 11.57 B  |                    |

Means sharing the same letter are not significantly different at  $p \leq 0.05$  according to Duncan's test

### Fruit volume

According to table (3), fruit volume was significantly influenced by pollen source and chelated zinc application, whereas pollination timing did not exert a significant effect. The highest fruit volume was obtained with mixed pollen source (Khadrawi + Berban), reaching  $11.47 \text{ cm}^3$ , while Khadrawi pollen produced the lowest value ( $10.54 \text{ cm}^3$ ). Similarly, foliar application of  $100 \text{ mg L}^{-1}$  chelated zinc increased fruit volume to  $11.66 \text{ cm}^3$  compared with  $10.58 \text{ cm}^3$  in control treatment. Regarding the two-way interactions, the combination of mixed pollen and pollination at 24 h resulted in greatest fruit volume ( $11.78 \text{ cm}^3$ ), whereas lowest value ( $10.09 \text{ cm}^3$ ) was recorded for Khadrawi pollen under same pollination timing. The interaction between pollen source and zinc application showed a maximum fruit volume of  $12.50 \text{ cm}^3$  with mixed pollen and  $100 \text{ mg L}^{-1}$  zinc, while the minimum value ( $9.58 \text{ cm}^3$ )

occurred in Khadrawi pollen without zinc application. Likewise, pollination at 24 h combined with  $100 \text{ mg L}^{-1}$  zinc produced largest fruit volume ( $12.25 \text{ cm}^3$ ), whereas smallest value ( $10.05 \text{ cm}^3$ ) was observed with 24 h pollination and  $50 \text{ mg L}^{-1}$  zinc. A significant three-way interaction was detected among the studied factors. The treatment combining mixed pollen (Khadrawi + Berban), pollination at 24 h, and  $100 \text{ mg L}^{-1}$  chelated zinc achieved highest fruit volume ( $14.16 \text{ cm}^3$ ), whereas lowest value ( $8.75 \text{ cm}^3$ ) was recorded in Khadrawi pollen with 24 h pollination under control treatment.

**Table 3. Effects of pollen source, pollination time, and chelated zinc application on fruit volume (g) of 'Barhee' date palm.**

| Pollen source                   | Chelated zinc<br>$\text{mg L}^{-1}$ | Pollination time |           | Pollen source $\times$ chelated<br>zinc |
|---------------------------------|-------------------------------------|------------------|-----------|-----------------------------------------|
|                                 |                                     | 24 h             | 72 h      |                                         |
| Khadrawi                        | 0                                   | 8.750 d          | 10.41 bcd | 9.58 c                                  |
|                                 | 50                                  | 9.750 cd         | 11.50 bc  | 10.62 bc                                |
|                                 | 100                                 | 11.79 b          | 11.06 bc  | 11.42 ab                                |
| Berban                          | 0                                   | 11.16 bc         | 11.00 bc  | 11.08 b                                 |
|                                 | 50                                  | 10.33 bcd        | 10.91 bc  | 10.62 bc                                |
|                                 | 100                                 | 10.82 bc         | 11.33 bc  | 11.07 b                                 |
| Mixed<br>(Khadrawi +<br>Berban) | 0                                   | 11.11 bc         | 11.08 bc  | 11.10 b                                 |
|                                 | 50                                  | 10.08 bcd        | 11.58 bc  | 10.83 b                                 |
|                                 | 100                                 | 14.16 a          | 10.83 bc  | 12.50 a                                 |

| pollen source x Pollination time |          |           | Mean pollen source |
|----------------------------------|----------|-----------|--------------------|
| Khadrawi                         | 10.09 c  | 10.99 abc | 10.54 B            |
| Berban                           | 10.77 bc | 11.08 ab  | 10.92 AB           |
| Mixed (Khadrawi + Berban)        | 11.78 a  | 11.16 ab  | 11.47 A            |
| Chelated zinc x Pollination time |          |           | Mean Chelated zinc |
| 0                                | 10.34 cd | 10.83 bcd | 10.58 B            |
| 50                               | 10.05 d  | 11.33 b   | 10.69 B            |
| 100                              | 12.25 a  | 11.07 bc  | 11.66 A            |
| Mean Pollination time            | 10.88 A  | 11.08 A   |                    |

Means sharing the same letter are not significantly different at  $p \leq 0.05$  according to Duncan's test

### Total yield

Table (4) demonstrates that total yield was significantly affected by pollen source and pollination timing, whereas chelated zinc application had no significant effect. The mixed pollen source (Khadrawi + Berban) produced the highest total yield ( $135.9 \text{ kg palm}^{-1}$ ), while Berban pollen recorded the lowest value ( $124.0 \text{ kg palm}^{-1}$ ). Likewise, pollination at 24 h resulted in a greater yield ( $134.7 \text{ kg palm}^{-1}$ ) compared with pollination at 72 h ( $122.9 \text{ kg palm}^{-1}$ ). For the two-way interactions, highest total yield ( $148.5 \text{ kg palm}^{-1}$ ) was achieved by combining mixed pollen with pollination at 24 h, whereas lowest ( $113.3 \text{ kg palm}^{-1}$ ) was obtained from Khadrawi pollen with pollination at 72 h. In pollen source  $\times$  zinc interaction, mixed pollen combined with  $100 \text{ mg L}^{-1}$

chelated zinc produced maximum yield ( $153.3 \text{ kg palm}^{-1}$ ), while minimum ( $113.7 \text{ kg palm}^{-1}$ ) was recorded for Berban pollen with  $50 \text{ mg L}^{-1}$  zinc. Similarly, interaction between pollination timing and zinc application showed highest yield ( $144.2 \text{ kg palm}^{-1}$ ) at 24 h pollination with  $100 \text{ mg L}^{-1}$  zinc, whereas lowest ( $122.6 \text{ kg palm}^{-1}$ ) was observed at 24 h pollination with  $50 \text{ mg L}^{-1}$  zinc. A significant three-way interaction was also detected, where combination of mixed pollen (Khadrawi + Berban), pollination at 24 h, and  $100 \text{ mg L}^{-1}$  chelated zinc resulted in highest total yield ( $176.5 \text{ kg palm}^{-1}$ ). In contrast, lowest yield ( $103.6 \text{ kg palm}^{-1}$ ) was recorded for Berban pollen with 24 h pollination and  $50 \text{ mg L}^{-1}$  chelated zinc.

**Table 4. Effects of pollen source, pollination time, and chelated zinc application on total yield (Kg) of 'Barhee' date palm.**

| Pollen source        | Chelated zinc<br>$\text{mg L}^{-1}$ | Pollination time |           | Pollen source $\times$ chelated<br>zinc |
|----------------------|-------------------------------------|------------------|-----------|-----------------------------------------|
|                      |                                     | 24 h             | 72 h      |                                         |
| Khadrawi             | 0                                   | 154.6 de         | 127.9 bcd | 141.2 c                                 |
|                      | 50                                  | 130.9 bcd        | 120.8 bcd | 125.8 abc                               |
|                      | 100                                 | 133.9 bcd        | 90.97 bcd | 112.4 bc                                |
| Berban               | 0                                   | 122.3 cde        | 130.5 b   | 126.4 abc                               |
|                      | 50                                  | 103.6 e          | 123.9 bc  | 113.7 c                                 |
|                      | 100                                 | 121.9 bcd        | 141.9 bc  | 131.9 abc                               |
| Mixed<br>(Khadrawi + | 0                                   | 135.6 bcd        | 113.6 b   | 124.6 ab                                |
|                      | 50                                  | 133.3 bcd        | 126.2 bcd | 129.7 bc                                |

|                                  |     |          |           |                    |
|----------------------------------|-----|----------|-----------|--------------------|
| Berban)                          | 100 | 176.5 a  | 130.2 bcd | 153.3 a            |
| pollen source x Pollination time |     |          |           | Mean pollen source |
| Khadrawi                         |     | 139.8 bc | 113.3 b   | 126.5 B            |
| Berban                           |     | 115.9 c  | 132.1 a   | 124 B              |
| Mixed (Khadrawi + Berban)        |     | 148.5 a  | 123.4 ab  | 135.9 A            |
| Chelated zinc x Pollination time |     |          |           | Mean Chelated zinc |
| 0                                |     | 137.5 b  | 124 a     | 130.7 A            |
| 50                               |     | 122.6 b  | 123.7 a   | 123.1 A            |
| 100                              |     | 144.2 a  | 121 ab    | 132.6 A            |
| Mean Pollination time            |     | 134.7 A  | 122.9 B   |                    |

Means sharing the same letter are not significantly different at  $p \leq 0.05$  according to Duncan's test

### Average flesh weight

Table (5) indicates that flesh weight was significantly affected by pollen source, pollination timing, and chelated zinc application. The mixed pollen treatment (Khadrawi + Berban) produced the highest flesh weight (11.47 g), whereas Berban pollen recorded the lowest value (10.79 g). Pollination at 24 h increased flesh weight to 11.29 g compared with 10.87 g at 72 h. Among zinc treatments, 50 mg L<sup>-1</sup> resulted in the highest flesh weight (11.26 g), while the control treatment showed the lowest value (10.81 g).

Regarding the two-way interactions, highest flesh weights were obtained from mixed pollen

with 24 h pollination (11.96 g), mixed pollen with 100 mg L<sup>-1</sup> chelated zinc (11.87 g), and 24 h pollination combined with 100 mg L<sup>-1</sup> zinc (11.74 g). In contrast, lowest values were recorded for Berban pollen with 72 h pollination (10.60 g), Berban pollen with 100 mg L<sup>-1</sup> zinc (10.47 g), and 24 h pollination without zinc application (10.49 g). The three-way interaction was significant, with combination of mixed pollen, 24 h pollination, and 50 or 100 mg L<sup>-1</sup> chelated zinc producing the greatest flesh weight (12.70 and 12.71 g, respectively). The lowest value (9.58 g) was observed in Berban pollen with 72 h pollination and 100 mg L<sup>-1</sup> chelated zinc.

**Table 5. Effects of pollen source, pollination time, and chelated zinc application on flesh weight (g) of 'Barhee' date palm.**

| Pollen source                    | Chelated zinc<br>mg L <sup>-1</sup> | Pollination time |          | Pollen source × chelated<br>zinc |
|----------------------------------|-------------------------------------|------------------|----------|----------------------------------|
|                                  |                                     | 24 h             | 72 h     |                                  |
| Khadrawi                         | 0                                   | 10.58 bc         | 10.74 b  | 10.66 c                          |
|                                  | 50                                  | 11.02 b          | 10.77 b  | 10.89 bc                         |
|                                  | 100                                 | 11.03 b          | 11.43 b  | 11.23 abc                        |
| Berban                           | 0                                   | 10.41 bc         | 11.52 b  | 10.96 bc                         |
|                                  | 50                                  | 11.19 b          | 10.70 bc | 10.95 bc                         |
|                                  | 100                                 | 11.37 b          | 9.580 c  | 10.47 c                          |
| Mixed<br>(Khadrawi +<br>Berban)  | 0                                   | 10.48 bc         | 11.10 b  | 10.79 c                          |
|                                  | 50                                  | 12.70 a          | 10.81 b  | 11.75 ab                         |
|                                  | 100                                 | 12.71 a          | 11.03 b  | 11.87 a                          |
| pollen source x Pollination time |                                     |                  |          | Mean pollen source               |

|                                  |         |          |                    |
|----------------------------------|---------|----------|--------------------|
| Khadrawi                         | 10.92 b | 11.02 b  | 10.97 B            |
| Berban                           | 10.99 b | 10.60 b  | 10.79 B            |
| Mixed (Khadrawi + Berban)        | 11.96 a | 10.98 b  | 11.47 A            |
| Chelated zinc x Pollination time |         |          | Mean Chelated zinc |
| 0                                | 10.49 b | 11.12 ab | 10.81 B            |
| 50                               | 11.64 a | 10.87 b  | 11.26 A            |
| 100                              | 11.74 a | 10.60 b  | 11.17 AB           |
| Mean Pollination time            | 11.29 A | 10.87 B  |                    |

Means sharing the same letter are not significantly different at  $p \leq 0.05$  according to Duncan's test

### Flesh-to-seed ratio

Table (6) shows that pollen cultivars and pollination times did not significantly affect the kernel-to-stone weight ratio, whereas chelated zinc significantly increased this trait, with the highest value recorded at 50 mg L<sup>-1</sup> (17.53%) compared with the control (12.67%).

Significant interactions were observed among the studied factors. Khadrawi pollen with pollination within 24 h produced the highest ratio (26.00%), while Berban pollen with pollination within 24 h gave the lowest (10.77%). Pollination within 24 h combined with 100 mg L<sup>-1</sup> zinc resulted in the highest

value (21.34%), whereas the same pollination time without zinc gave the lowest (9.71%). The interaction between pollen cultivar and zinc concentration was significant; mixed pollen (Khadrawi + Berban) with 50 mg L<sup>-1</sup> zinc produced the highest ratio (16.59%), while Khadrawi pollen with 100 mg L<sup>-1</sup> zinc recorded the lowest (7.12%). The highest value under the three-way interaction was obtained from mixed pollen, pollination within 24 h, and 50 mg L<sup>-1</sup> zinc (14.58%), whereas the lowest value was recorded with mixed (Khadrawi + Berben) pollen, pollination within 24 h, and control (10.80%).

**Table 6. Effects of pollen source, pollination time, and chelated zinc application on Flesh-to-seed ratio of 'Barhee' date palm.**

| Pollen source                    | Chelated zinc<br>mg L <sup>-1</sup> | Pollination time |           | Pollen source × chelated<br>zinc |
|----------------------------------|-------------------------------------|------------------|-----------|----------------------------------|
|                                  |                                     | 24 h             | 72 h      |                                  |
| Khadrawi                         | 0                                   | 11.25 d          | 20.65 cd  | 15.95 d                          |
|                                  | 50                                  | 24.98 bcd        | 9.750 cd  | 16.39 cd                         |
|                                  | 100                                 | 11.03 bcd        | 13.13 ab  | 12.08 ab                         |
| Berban                           | 0                                   | 31.54 cd         | 13.09 ab  | 22.31 bc                         |
|                                  | 50                                  | 13.01 cd         | 11.50 bcd | 12.25 bcd                        |
|                                  | 100                                 | 12.92 ab         | 9.037 bc  | 10.97 ab                         |
| Mixed<br>(Khadrawi +<br>Berban)  | 0                                   | 10.80 cd         | 15.41 bcd | 13.10 cd                         |
|                                  | 50                                  | 14.58 a          | 18.60 bc  | 16.59 a                          |
|                                  | 100                                 | 13.66 e          | 12.69 bcd | 13.17 d                          |
| pollen source x Pollination time |                                     |                  |           | Mean pollen source               |
| Khadrawi                         |                                     | 26.00 b          | 25.62 ab  | 25.81 A                          |

|                                  |          |          |                    |
|----------------------------------|----------|----------|--------------------|
| Berban                           | 10.77 ab | 11.04 a  | 10.90 A            |
| Mixed (Khadrawi + Berban)        | 12.84 b  | 15.22 ab | 14.03 A            |
| Chelated zinc x Pollination time |          |          | Mean Chelated zinc |
| 0                                | 9.712 c  | 15.63 b  | 12.67 B            |
| 50                               | 15.70 c  | 19.37 b  | 17.53 A            |
| 100                              | 21.34 a  | 12.61 ab | 16.97 B            |
| Mean Pollination time            | 15.59 A  | 15.87 A  |                    |

Means sharing the same letter are not significantly different at  $p \leq 0.05$  according to Duncan's test

The results presented in Tables (1–5) revealed that pollen sources had a significant effect on the physical characteristics of date palm fruits. The mixed pollen source (Khadrawi + Barben) outperformed the other treatments in most studied traits of tissue-cultured 'Barhi' date palms, including fruit set percentage, average fruit weight, fruit volume, total yield, and pulp

weight. This superiority may be attributed to the high fertilization efficiency of this pollen mixture, as well as possible differences in compatibility between the pollen sources and the 'Barhi' cultivar [10]. Variations in fruit set are known to depend strongly on pollen origin, which significantly influences fertilization success depending on cultivar response [11].

The increase in fruit size may be explained by the positive role of high-quality pollen in enhancing ovary and embryo development [12]. Moreover, the improvement in total yield under the mixed pollen treatment is likely associated with increases in fruit weight, size, and dimensions, which collectively contribute to higher overall production.

These differences in fruit set may also be linked to the phenomenon of metaxenia, where pollen sources influence fruit quality and biochemical properties independent of the embryo and endosperm. Pollen origin can affect fruit chemical and physiological characteristics, including soluble sugar content, thereby enhancing fruit ripening, size, and weight [13]. These findings are consistent with those reported by [14] and [15], who observed significant effects of different pollen sources on fruit physical and quality traits in various date palm cultivars.

The results in tables (2, 4, and 5) also indicated that pollination timing had a

significant effect on fruit physical traits. Pollination within 24 hours produced superior results in fruit weight, total yield, and pulp weight in tissue-cultured 'Barhee' palms. This effect may be attributed to the importance of synchronizing pollination with stigma receptivity, which is critical in dioecious fruit species such as date palm. Optimal pollination timing, typically ranging from spathe cracking to up to ten days afterward, has been reported to maximize fruit set and yield [16],[17]. Early pollination may overcome structural abnormalities in stigmas that can inhibit pollen tube growth and lead to poor fruit set [18]. Higher fruit set within 24 hours may therefore result from pollination occurring before the development of such anatomical barriers, allowing more efficient pollen tube growth and fertilization. These findings agree with [19] and [20], who reported significant improvements in fruit set, size, and weight with optimized pollination timing.

Tables (1, 3, 5, and 6) further showed that foliar application of chelated zinc significantly

influenced the physical characteristics of date palm fruits, including fruit set percentage, fruit volume, pulp weight, and pulp-to-seed ratio. The 100 mg L<sup>-1</sup> concentration showed superiority in most traits, while 50 mg L<sup>-1</sup> was more effective in improving pulp weight and pulp-to-seed ratio. The beneficial effects of zinc may be attributed to its chelated form, which enhances nutrient uptake efficiency and bioavailability [21] , [22]. Zinc also plays a crucial role in regulating reactive oxygen

species and protecting plant cells from oxidative stress [23] and [24] , thereby improving fruit size, maturity rate, and pulp quality. Additionally, zinc is essential for nucleic acid metabolism, enzyme activation, and physiological regulation, which collectively enhance fruit quality traits, including pulp-to-seed ratio. These results are consistent with [25] who reported significant improvements in pulp-to-seed ratio in mango following foliar zinc application.

## References

- [1] Al-Karmadi, A., & Okoh, A. I. (2024). An overview of date (*Phoenix dactylifera* L.) fruits as an important global food resource. *Foods*, 13(7), 1024.
- [2] Al-Habsi, N. (2025). Date palm (*Phoenix dactylifera* L.) fruit: Strategic crop for food security, nutritional benefits, postharvest quality, and valorization into emerging functional products. *Sustainability*, 17(16), 7491.
- [3] Mahomoodally, M. F., Khadaroo, S. K., Hosenally, M., Zengin, G., Rebezov, M., Ali Shariati, M., & Simal-Gandara, J. (2024). Nutritional, medicinal and functional properties of different parts of the date palm and its fruit (*Phoenix dactylifera* L.)—A systematic review. *Critical reviews in food science and nutrition*, 64(22), 7748-7803.
- [4] Kadri, K., Jemni, M., Mesnoua, M., Sharma, S. S., Malik, A. A., Makhoulf, S., & Elsafy, M. (2024). Study on the effects of pollen sources on the agronomic, biochemical, mineral, and pomological traits of date palm (*Phoenix dactylifera* L.) cv 'Deglet Nour' fruits in Degache Oases (Tunisia). *Genetic Resources and Crop Evolution*, 71(7), 3721-3733.
- [5] Khan, B. A., Nazir, M. J., Khan, R., Din, N. U., & Haq, E. U. (2025). Response of Different Concentrations of Liquid Pollen Applications on Fruit Set, Yield and Fruit Physical Properties of Dhakki and Zahidi Date Palm: (*Phoenix dactylifera* L.) under the Agro-Ecological Conditions of Dera Ismail Khan. *International Journal of Agriculture Innovations and Cutting-Edge Research (HEC Recognised)*, 3(3), 67-78.
- [6] Souri, M. K., & Hatamian, M. (2019). Aminochelates in plant nutrition: a review. *Journal of plant nutrition*, 42(1), 67-78.
- [7] Poudel, P., Connolly, E. L., Kwasniewski, M., Lambert, J. D., & Di Gioia, F. (2024). Zinc biofortification via fertigation using alternative zinc sources and concentration levels in pea, radish, and sunflower microgreens. *Scientia Horticulturae*, 331, 113098.
- [8] Ream, C.L. 1976. Metaxenia effect of pollen from inbred male palm On ripening period and size of date fruit . *Date Growers Inset .Rept .* 53;21-22(Hort .Abstr .48 ;2828).
- [9] Al-Dhahab, Imad Abdul Karim Mohammed Rida.(2010). Effect of bunch thinning and

- ethephon spraying on fruit ripening percentage and yield characteristics of date palm (*Phoenix dactylifera* L.) cv. Shakar. Master's thesis, College of Agriculture, University of Basrah, Iraq.
- [10] Iqbal .M, Niamatullah M, Munir M. 2012. Effect of various *Dactylifera* male pollinizers on pomological traits and economical yield index of cvs. 'Shakri', 'Zahidi' and 'Dhakki' date palm (*Phoenix dactylifera* L.). *The Journal of Animal & Plant Sciences* 22, 376-383.
- [11] Islam SE. (2017). Evaluation of date palm types as pollinators for Zaghloul and Samany date palm cvs. grown in Qalyubia governorate. *Middle East Journal of Agriculture Research*. 1049-1056.
- [12] Zargari H, Talaei A, DehghaniShuraki Y, Abdousi V. 2021. An Investigation into the effect of different pollen sources on fruit set of palms obtained from tissue culture and offshoot of 'Barhi', 'Piarom' and 'Mazafati' cultivars. *Journal of Crops Improvement*, 23(4), 767- 785.
- [13] Maryam, Ahmad, I., Nafees, M., Saqib, M., Alwhibi, M. S., Elshikh, M. S., & Iqbal, R. (2025). Effect of pollen sources on biochemical indices and hybrid authentication in date palm (*Phoenix dactylifera* L.) cv. Khadrawy. *Genetic Resources and Crop Evolution*, 1-15.
- [14] El-Rauof, F. A. (2022). Effect of different pollen sources on yield and fruit quality of barhi date palm cultivar under Sudan conditions. *Egyptian International Journal of Palms*, 2(1), 60-68.
- [15] El-Kosary, S., Himmam, I., Qenawy, Y. G., and EG, G.(2023). Comparative Study of The Physico-Chemical Properties between Some Pollinizers for. *Egyptian Journal of Chemistry*, 66(8): 219-225.
- [16] Iqbal, M., Ghaffoor, A., Rehman, S., 2004. Effect of pollination times on fruit characteristics and yield of date palm cv. Dhakki. *Intl. J. Agric. Biol.* 6, 96–99.
- [17] Nasr, T.A., Bacha, M.A., Shaheen, M.A., (1988). Receptivity of pistillate flowers in some date palm cultivars in riyaadh region. *J. Coll. Agric. King Saud Univ.* 10 (1), 121–128.
- [18] Cohen, Y., Korchinsky, R., & Tripler, E. (2004). Flower abnormalities cause abnormal fruit setting in tissue culture-propagated date palm (*Phoenix dactylifera* L.). *The Journal of Horticultural Science and Biotechnology*, 79(6), 1007-1013.
- [19] Shahid, M. A., Iqbal, M., Khan, I., Ahmed, S., Niamatullah, M., & Munir, M. (2020). Effect of pollination time to improve physicochemical characteristics of 'dhakki' dates. *J Appl Hortic*, 17(3), 49-57.
- [20] Mohammadi, N., Rastgoo, S., & Izadi, M. (2017). The strong effect of pollen source and pollination time on fruit set and the yield of tissue culture-derived date palm (*Phoenix dactylifera* L.) trees cv. Barhee. *Scientia Horticulturae*, 224, 343-350.
- [21] Mohammadi, A.H.; Aboutalebi, A.H. and Hassanzadeh, H. (2008). Effect of plant growth regulators on quantitative and qualitative characteristics Mohamm of Shahani date fruit. *J. of Research in Agricultural Sciences* 4(2), 204-212.
- [22] Jahromi, A.A. and Naseri, B. (2015). Amino chelate with micronutrients and calcium had effect on date fruit characteristics. *Inter. J. of Biosc.*, 6 (3): 313-318.
- [23] Amiri, A. B., Baninasab, C. Ghobadi, A. and Khoshgoftarmanesh, H .(2016). Zinc

soil application enhances photosynthetic capacity and antioxidant enzyme activities in almond seedlings affected by salinity stress. *Photosynthetic*, 54(2): 267-274.

- [24] Faizan, M.A., Faraz, M., Yusuf, S. T. and Khan, S. H., 2017. Zinc oxide nanoparticle-mediated changes in photosynthetic efficiency and antioxidant

system of tomato plants. *Photosynthetica*, 55(4):1-9.

- [25] Verma, M. et al. (2025). Influence of Pre-Harvest Foliar Application of Naphthalene Acetic Acid and Zinc Sulphate on Fruit Retention, Yield and Quality Parameters of Mango. *Plant Archives*, 25(1): 2075–2079.