Study On The Effect Of Different Pollen Sources, Multiple Pollination Methods, And Pollination Frequency In Khastaawi Date Palm On Quantitative And Qualitative Traits Of Yield

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Abstract

Date palm cultivation is one of the fundamental crops in Iraq, due to its economic, nutritional, and strategic importance within the national food security system. Given that climate changes in Iraq have had negative effects, this study aimed to investigate the impact of pollination sources, pollination methods, and pollination frequency on the chemical and productive traits of this cultivar. The study also measured the anatomical characteristics of pollen grains by assessing shape, polarity, germination opening, wall thickness, and surface ornamentation, in addition to measuring the seed germination percentage of pollen in the laboratory for the three cultivars. The main factors included: First, pollen source (A), consisting of Red Ghnamee (A1), Green Ghnamee (A2), and Khakri (A3). Second, pollination method (B), consisting of: pollen suspension (B1), dry pollination (B2), and using four male catkins (stamens) (B3). Third, number of pollination repetitions (C), consisting of pollination one time (C1) and pollination twice (C2). The experiment was conducted according to a randomized complete block design (RCBD) in a factorial arrangement with three replications. Across all pollen sources, fruit set generally increases as it moves from B1 to B3 and from C1 to C2, as in figure 1a. For instance, B3C2 tends to yield the highest fruit set, while B1C1 tends to yield the lowest. By pollen source (A1, A2, A3); A1 values rise from B1C1 (70.00) to B3C2 (77.08); A2 (Green Ghnamee): values rise from B1C1 (65.52) to B3C2 (69.40); A3 (Khakri): values rise from B1C1 (60.35) to B3C2 (65.14). Across pollination methods and repetitions, fruit drop percentages decline from B1C1 to B3C2; For A1 drop goes from 30.00% (B1C1) down to 22.91% (B3C2); For A2 drop goes from 34.48% (B1C1) down to 30.26% (B3C2); For A3 drop goes from 39.65% (B1C1) down to 34.85% (B3C2). There were also significant differences for the main factors and the two-way interactions among the study variables. The results showed that the pollen source type, pollination method, and pollination repetition have clear significant effects on the productive and chemical traits of the date palm cultivar Khastaawi. The use of the Red Ghnamee pollen with repeated pollination using the traditional method contributed to improved fruit set percentage and reduced fruit drop, positively affecting the weight of the spike and the overall palm yield. The pollination treatments also increased total sugars percentage and reducing sugars percentage in the fruits, indicating the possibility of using these treatments to improve the fruit's chemical quality. The study recommends adopting effective pollen source materials and pollination repetition according to a studied schedule to enhance production efficiency in the Khastaawi date palm cultivar under similar environmental conditions.

Keywords: Date palm, pollen source, Pollination methods, number of pollinations

INTRODUCTION

Date palm (*Phoenix dactylifera* L.) is one of the economically important and widely cultivated trees worldwide, especially in the Arab world, due to its historical, economic, nutritional, and industrial value. The Khastaawi cultivar is widely grown in Iraq because it is characterized by abundant production and acceptable fruit quality [1]. Given this multi-dimensional importance, there is a need for continuous scientific studies aimed at improving economic yield and production quality of this vital crop [2].

Dates fruits contain a broad range of essential nutrients, making them highly nutritious and rich in antioxidants. Mature fruits largely contain sugars (about 80%) with lower amounts of protein, fiber, and trace elements, including boron, cobalt, copper, fluorine, magnesium, manganese, selenium, and zinc [3] [4]. The Khastaawi cultivar is a traditional variety with a strong market presence globally, providing a promising income source for local farmers [5].

The pollen source used for pollination in date palms directly and effectively influences many qualitative and chemical fruit traits, as fruit response varies according to pollen source in terms of fruit set percentage, growth rate, and ripening time, in addition to changes in chemical composition such as total sugars and

reducing sugars, among others [6] [7]. Pollination of date palms is a highly important process that directly affects fruit set, quality, and productivity.

Natural pollination by wind, bees, and other insects can lead to poor-quality fruits, uneven sizes, seedlessness, crowding in the inflorescence, shriveling, drying, and browning, resulting in fruit drop [8] [9] [10]. Therefore, both manual pollination and automated pollination are among the most efficient methods for delivering pollen directly to the pistils of the female flowers. These methods allow precise control over the amount and quality of the pollen used, in addition to timing pollination to suit the flower-opening stage, and this precision in application leads to increased fruit set and better distribution of fruits on the stalk, positively affecting the quality and quantity of production [11] [12].

Additionally, the repetition of the pollination process has a significant impact on improving fruit quality traits, with studies showing that repeated pollination contributes effectively to enhancing the quality of the fruits and improving their marketability [13] [14] [15].

Given the production and tolerance challenges faced by the Khastaawi date palm under adverse environmental conditions, this study aimed to explore ways to improve the productive and qualitative performance of this cultivar by studying the effects of different pollen sources, pollination methods, and pollination repetitions, with the goal of identifying the best treatments that enhance fruit set efficiency and improve fruit quality under local conditions.

MATERIALS AND METHODS

This experiment was conducted during the 2024 growing season in a local date palm garden located in the village of Al-Jazira, about 25 km west of Ramadi city in the Anbar province, on the banks of the Euphrates River, from March until the end of September. The study aimed to assess the effect of pollen source, pollination method, and pollination frequency on the quantitative and qualitative traits of the date palm cv. Khastaawi. Fifty-four date palms, 15 years old, uniform in growth and free of disease and insect injuries, were selected and planted at equal spacings (8 × 8 m).

These trees were irrigated with Euphrates River water, and ten inflorescences per palm were retained, distributed across the four directions to ensure uniform experimental units.

Study factors

The study included three main factors:

- Pollen source: Red Ghnamee (A1), Green Ghnamee (A2), Khakri (A3).
- Pollination method: suspension spray (B1), dry pollination (B2), traditional method (B3).
- Number of pollination repetitions: one pollination (C1) and two pollinations (C2).

Pollination was performed using the first method by dissolving pollen in a suspension (water) at a ratio of 1:3 g L^{-1} [16], designated as B1. The second method mixes pollen with flour at a 2:1 ratio, designated as B2 [17]. The third method uses four catkins and is designated as B3 [18]. The three methods were applied for each pollen source. Repetition of pollination was done once for part of the palms (C1) and twice for the other part (C2) seven days after the first pollination [19].

Accompanying agricultural operations included insect control (control of red palm weevil and stem borer) and conditioning of all inflorescences for all experimental units, as well as removing inflorescences infected with the disease "Khiyas al- Tal" (note: transliteration; exact disease name may vary). A complete randomized block design (RCBD) with a factorial arrangement and three replications was used. Data were analyzed with GenStat statistical software, and means were compared using the Least Significant Difference (L.S.D) test at a 0.05 probability level [20].

Traits studied

Percentage of Fruit Set (%)

This trait was estimated in mid-September. Five random male inflorescences were selected from each inflorescence, then the number of formed fruits and the number of barren sites (empty fruit positions) in each inflorescence were counted, and the fruit set percentage was calculated according to the method proposed by Ream and Furr [21].

Percentage of Fruit Drop (%)

This trait was calculated when five inflorescences were randomly taken from each inflorescence, as described by [22].

Percentage of threshed fruit (%)

The percentage of threshed (husked) fruits is calculated when the fruits enter the date stage, according to the study of Al-Ibrisim [23]. Five catkins were taken from each inflorescence, and the percentage of threshed fruits was computed.

Total yield rate (kg.palm^{-1})
The total yield of each palm was obtained by summing the weight of every inflorescence and then computing the mean total weight per palm.
Weight of the fresh flesh of fruit (g)
The weight of the flesh of ten fruits randomly selected per experimental unit was measured. The seeds were removed from the fruit flesh, and the flesh weight per fruit was measured with a precise balance.
Weight of the seeds (g)
Ten samples were weighed per treatment with a precise balance, and the mean seed weight was obtained by dividing the total by the number of seeds.
Percentage of total sugars (%)
Sugars were estimated according to the method of Joslyn [24].
Percentage of non-reducing sugars (sucrose) (%)
Calculated using the following formula [25]
Non-reducing sugars (sucrose) = total sugars % – reducing sugars %

RESULTS AND DISCUSSIONS

Across all pollen sources, fruit set generally increases as it moves from B1 to B3 and from C1 to C2, as in figure 1a. For instance, B3C2 tends to yield the highest fruit set, while B1C1 tends to yield the lowest. By pollen source (A1, A2, A3); A1 values rise from B1C1 (70.00) to B3C2 (77.08); A2 (Green Ghnamee): values rise from B1C1 (65.52) to B3C2 (69.40); A3 (Khakri): values rise from B1C1 (60.35) to B3C2 (65.14).

The pattern mirrors fruits set inversely as fruit set increases, fruit drop tends to decrease within each pollen source, as in figure 1b. Across pollination methods and repetitions, fruit drop percentages decline from B1C1 to B3C2; For A1 drop goes from 30.00% (B1C1) down to 22.91% (B3C2); For A2 drop goes from 34.48% (B1C1) down to 30.26% (B3C2); For A3 drop goes from 39.65% (B1C1) down to 34.85% (B3C2).

In general, C2 tends to yield modest gains in fruit set and modest reductions in fruit drop across all pollen sources. While Fruit set is highest for A1, especially under B3C2 (77.08%), and fruit drop is lowest for A1 under B3C2 (22.91%). Across pollen sources, the order is A1 > A2 > A3 for both higher fruit set and lower drop.
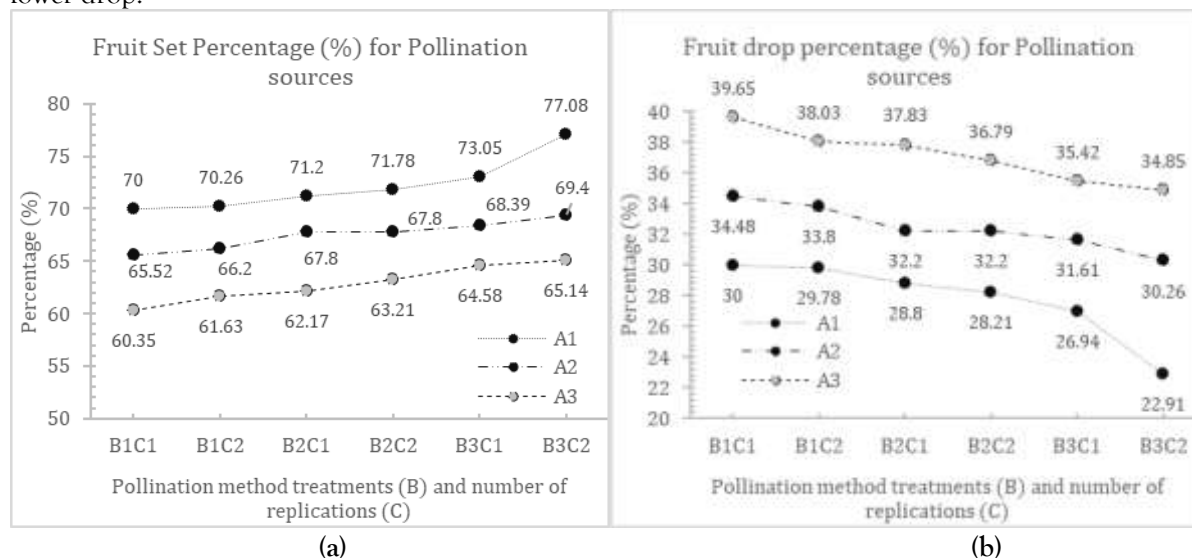

Figure 1: Fruit set and fruit drop percentages for pollination sources in relation with pollination method treatment and number of replications.

In correspondence for Kimri, A1 shows a general decreasing trend from B1C2 (6.7) to B3C2 (5.333) with some fluctuations as in figure 2, while, A2 tends to cluster between ~5.0 and ~5.8 with a mild dip; A3 shows the strongest drop from higher values to lower.
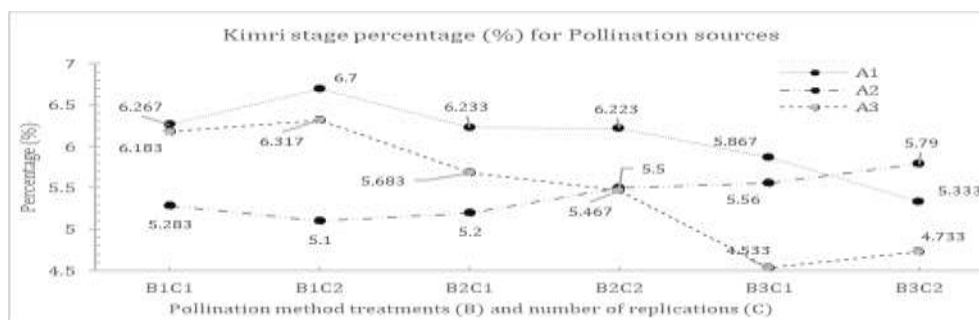
Figure 2: Kimri Stage Percentage for pollination sources in relation with pollination method treatment and number of replications.

As for Average total yield, A2 consistently yields the highest values across all combinations, with yields clustering around 189–194.5 kg palm⁻¹ as in figure 3; while A1 yields are moderate, increasing gradually from 154 up to 187.5, showing a steady upward trend across combinations. Also, A3 yields are the lowest among the three sources, rising from 131 to 153.5, though the rate of increase is similar to A1.

Furthermore, the trend across pollination combinations (B1C1 → B3C2) increases as it moves from B1C1 to B3C2. This suggests that, regardless of pollen source, more intensive pollination combinations (moving toward B3C2) tend to produce higher yields, with A2 showing the smallest incremental gain.
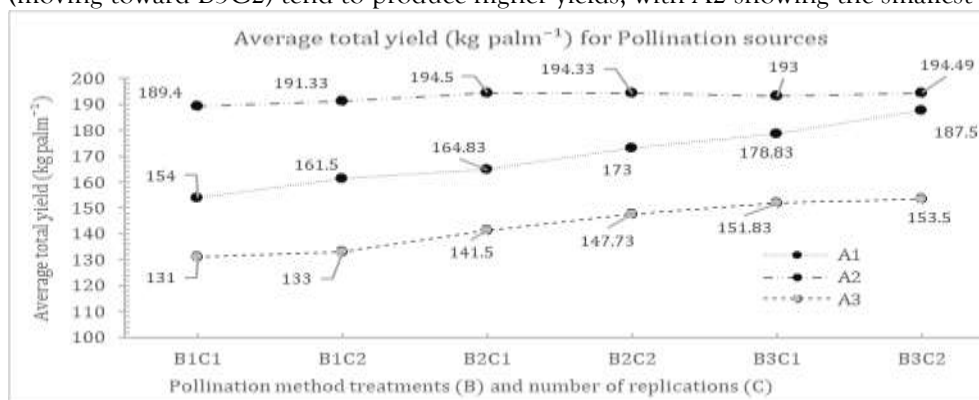

Figure 3: Average total yield in correspondence with pollination sources vs both pollination method treatment and number of replications.

Generally, the weight results show the following as in figure 4a; A1 yields the highest weights across all combinations, increasing from 6.80 to 7.10; A2 yields mid-range weights, increasing from 6.59 to 6.78; A3 yields the lowest weights overall, starting at 6.14 and ending at 6.65. For A3, there is a notable rise especially from B2C2 (6.73) to B3C2 (6.65) which is a slight decrease, but still increasing from B1C1 (6.14) to B3C2 (6.65). The gaps are relatively modest, with A1 typically ~0.2–0.5 g higher than A2, and A2 ~0.3–0.5 g higher than A3. For heavier fruit, A1 is the strongest pollen source, followed by A2 and A3. Increasing pollination intensity (toward B3C2) generally increases weight for A1 and A2; A3 shows a similar but slightly less pronounced pattern.

However, as in figure 4b, A1 yields the highest volumes across all combinations, increasing from 6.40 to 6.97 as we move from B1C1 to B3C2; A2 yields mid-level volumes, increasing from 5.40 to 6.30; A3 yields the lowest volumes, increasing from 4.33 to 5.17. Within each pollen source, volumes generally increase from B1C1 to B3C2, showing a positive response to more intensive pollination combinations.
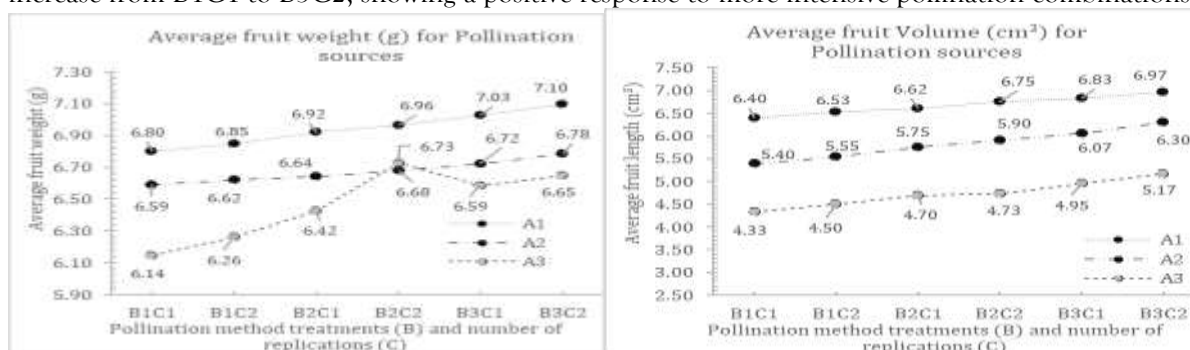
(a)   (b)

Figure 4: Average fruit volume and weight for pollination sources in relation with pollination method treatment and number of replications.

Generally, for all pollen sources, the pulp-to-fruit ratio is quite high and gradually decreasing as it moves from B1C1 to B3C2, as shown in figure 5. A3 consistently has the highest pulp fraction, followed by A2, then A1. This suggests Khakri (A3) yields proportionally more pulp relative to total fruit, compared with the others. There is slight downward drift for all A, meaning proportion of pulp relative to total fruit is decreasing as pollination intensity increases.

While the pit-to-fruit ratio increases with later combinations (weak upward trend), with A1 generally the highest, A3 the lowest. A1 has the highest pit fraction, then A2, then A3. There is an upward drift for all A, meaning more seeds per fruit relative to total fruit as pollination intensity increases.

Furthermore, Across combinations, moving toward B3C2 (the most intensive pollination) tends to increase both pulp fraction and seed fraction slightly for each pollen source, though the pulp-to-fruit ratio shows a small downward drift.
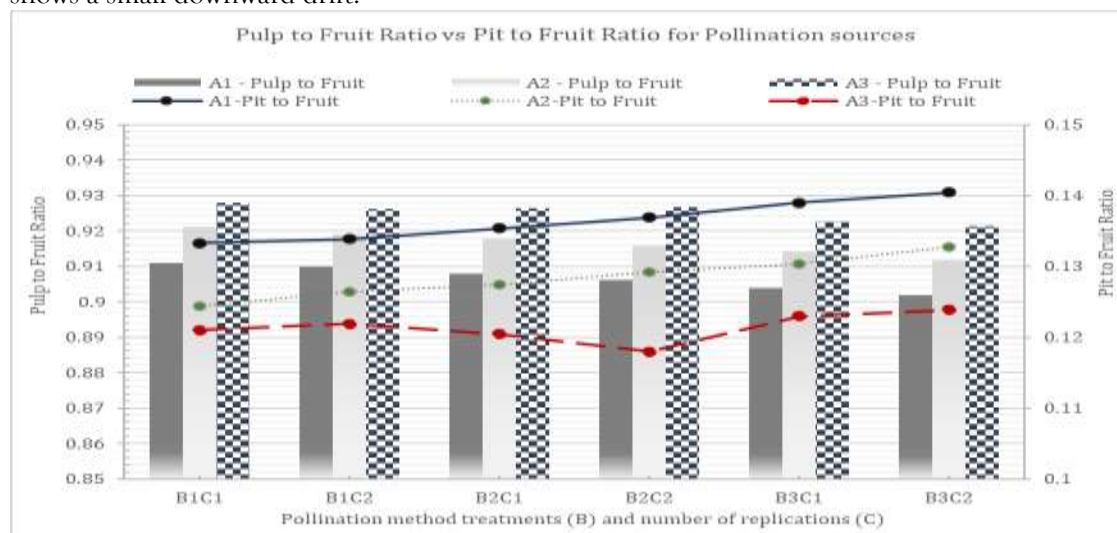

Figure 5: Pulp to fruit ratio and Pit to fruit ration for pollination sources in relation with pollination method treatment and number of replications.

In the aspect of Total Soluble Solids (TSS), as in figure 6, A1 consistently yields the highest TSS across all combinations; A2 yields intermediate TSS values; A3 yields the lowest TSS, with one notable dip at B1C2 (58.33). TSS generally increases as combinations become more intensive (toward B3C2); B3C2 often yields the highest TSS for A1 and A3, while A2 peaks at or near B3C1 or B3C2.

However, in the aspect of moisture content, A1 shows high moisture in several combos (notably B1C1 and B3C2), but also some low values (B1C2 around 24.65). A2 generally exhibits lower moisture in early combos but peaks at B3C1 (33.27), indicating more variability. A3 tends to be moderate, with values typically in the high 20s and approaching 30% in B3C2 (30.35). In many combos, A2 achieves higher moisture than A1 and A3 (e.g., B3C1: A2 = 33.27 vs A1 = 28.10, A3 = 28.71). A1 often has the highest moisture in B1C1, but this is not uniform across all combos.
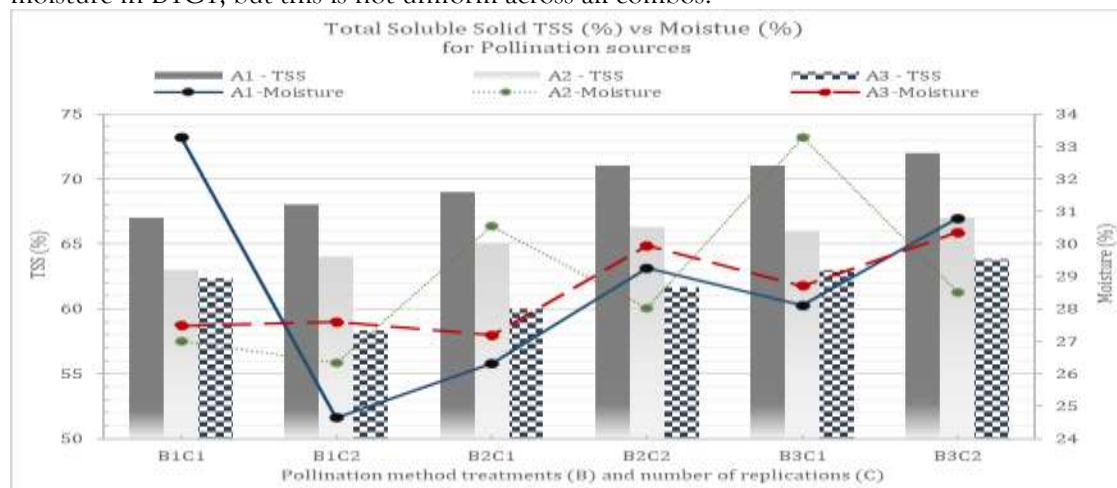

Figure 6: Total soluble solids TSS and Moisture content for pollination sources in relation with pollination method treatment and number of replications.

Generally, for pollen sources, A1 yields the highest total sugar percentages across all combinations; A2 yields intermediate values, generally 60–64%; A3 yields the lowest values, ranging from mid-50s to 60, as it noticed in figure 7. For each pollen source, total sugar tends to increase as we move toward B3C2, though A3 shows a dip at B2C2 (58) before rising again.

A3 often has the highest non-reducing sugar in several combos (notably B2C2: 6.63, B3C2: 6.83). A1 tends to be moderate, around 5.67–6.17, with a few higher points (6.17 at B1C2, B3C1/B3C2). A2 is more variable and sometimes lower (e.g., B1C2: 5.20; B3C2: 6.43). Non-reducing sugar values for A3 show an upward trend toward B3C2 (6.83 at B3C2 is the highest in the table). A1 shows relatively stable values with minor fluctuations around 5.6–6.2.
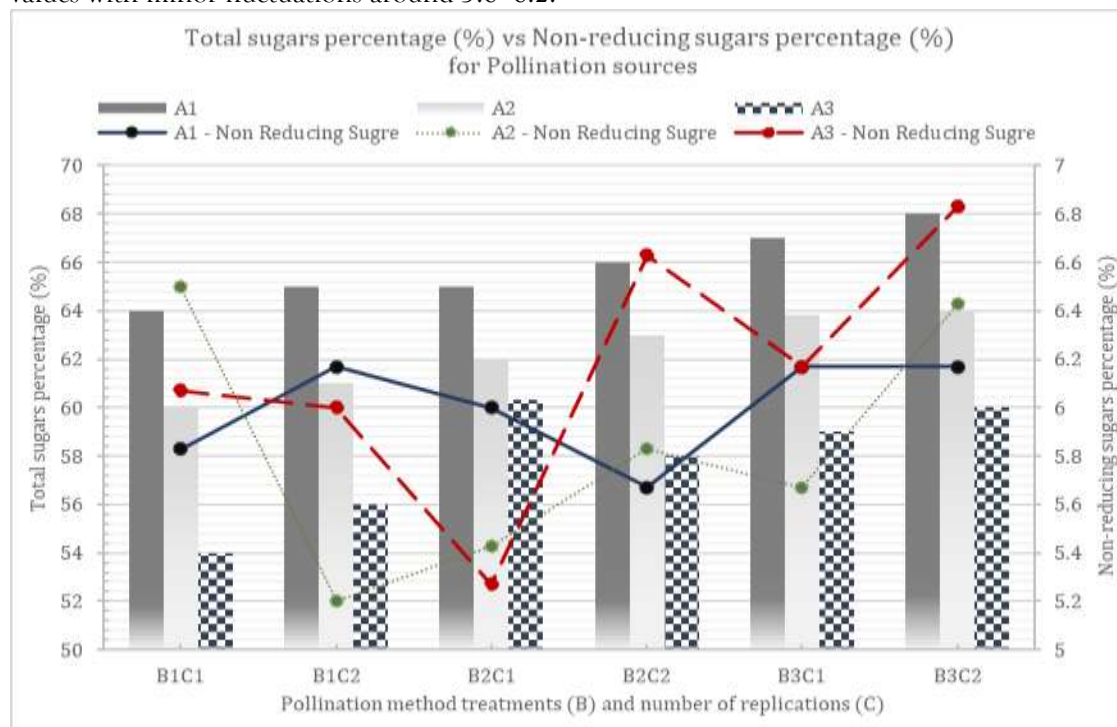

Figure 7: Total Sugar and Non-reducing sugar percentages for pollination sources in relation with pollination method treatment and number of replications

Figure (8) contains Taguchi analysis plots (Main Effects and Interaction plots) for two different metrics when larger is better for the responses, Fruit Set, volume and weight of fruit, pulp to fruit ratio, total sugar and total yield. The top two plots is for Means while the bottom two plots is Signal-to-Noise (S/N) Ratios.

Interaction plot for means shows interactions between factors A, B, and C. Each sub-plot corresponds to interaction between two factors while the third is kept constant. Where A-B interaction has significant interaction lines are not parallel, especially for factor A at level 2. However, A-C interaction has lines cross, indicating strong interaction. But, B-C interaction lines are nearly parallel refers to weak interaction.

Main effects plot for means displays effect of each factor (A, B, C) on the mean response. The A1 has the largest effect; Level 2 gives the highest mean, Level 3 the lowest. While C is almost flat refers to a negligible effect on mean response.

Interaction Plot for S/N Ratios shows A-B interaction lines is diverge significantly indicating strong interaction. While B-C interaction is nearly parallel indicating weak interaction. Furthermore, main effects plot for S/N Ratios shows the (A) has strong positive effect higher level improves robustness significantly. The B-factor has Small negative trend. While C has almost negligible impact.

Figure (9) contains Taguchi analysis plots when smaller is better for the responses, Fruit drop, Kimri and pit to fruit ratio. The top two plots are for Means while the bottom two plots are Signal-to-Noise (S/N) Ratios.
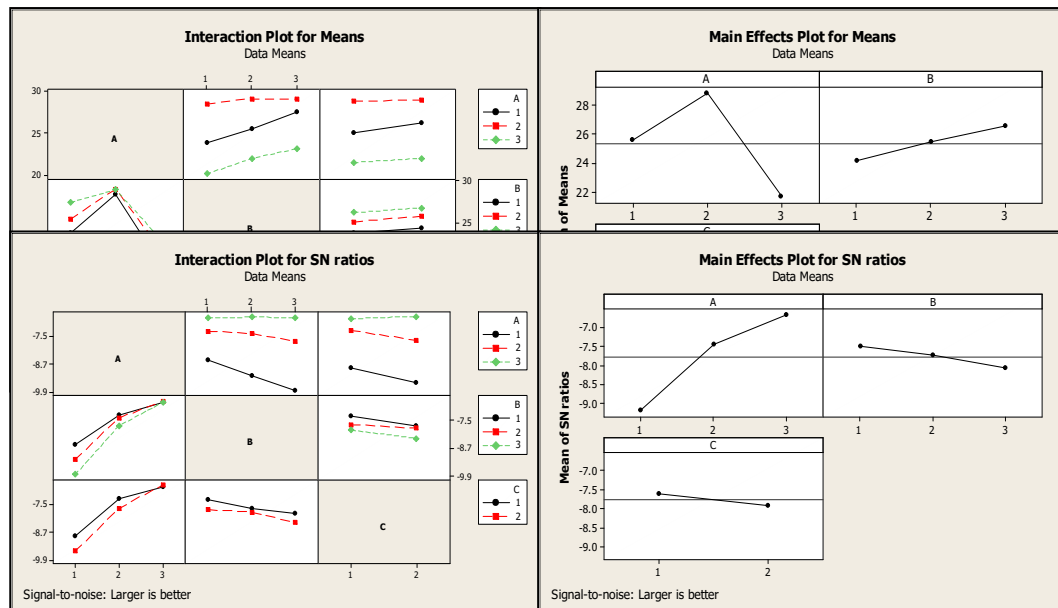
Figure 8: Taguchi analysis when larger is better; Main Effects and Interaction plots for Means in the top and for S/N ratio in the two bottoms
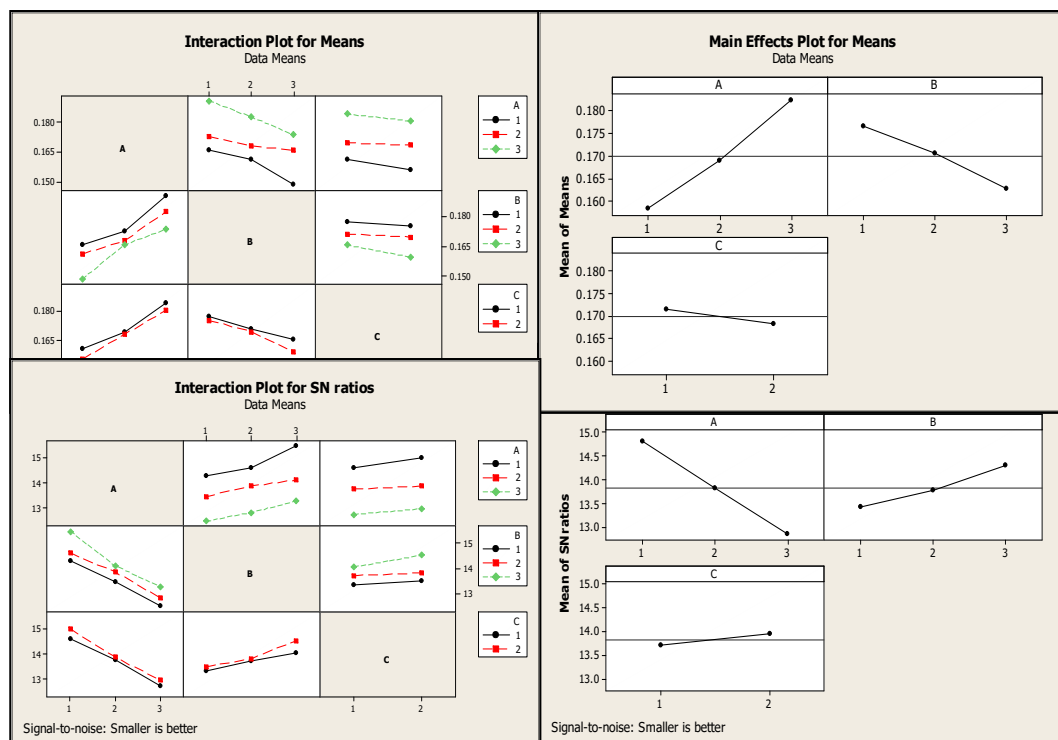

Figure 9: Taguchi analysis when smaller is better; Main Effects and Interaction plots for Means in the top and for S/N ratio in the two bottoms

The A-B interaction lines are not parallel indicating moderate interaction. While both A-C and B-C interaction lines are almost parallel refer to weak interaction. For means the lower means are better for that reason the best performance in A1, B3, C2 (because A1 and B3 minimize the mean). However, for lowest S/N ratio, the A3, B1, C1 is better at robustness.

Figure (10) contains Taguchi analysis plots when nominal is better for the responses, non-reducing sugar and moisture content. The top two plots are for Means while the bottom two plots are Signal-to-Noise (S/N) Ratios.
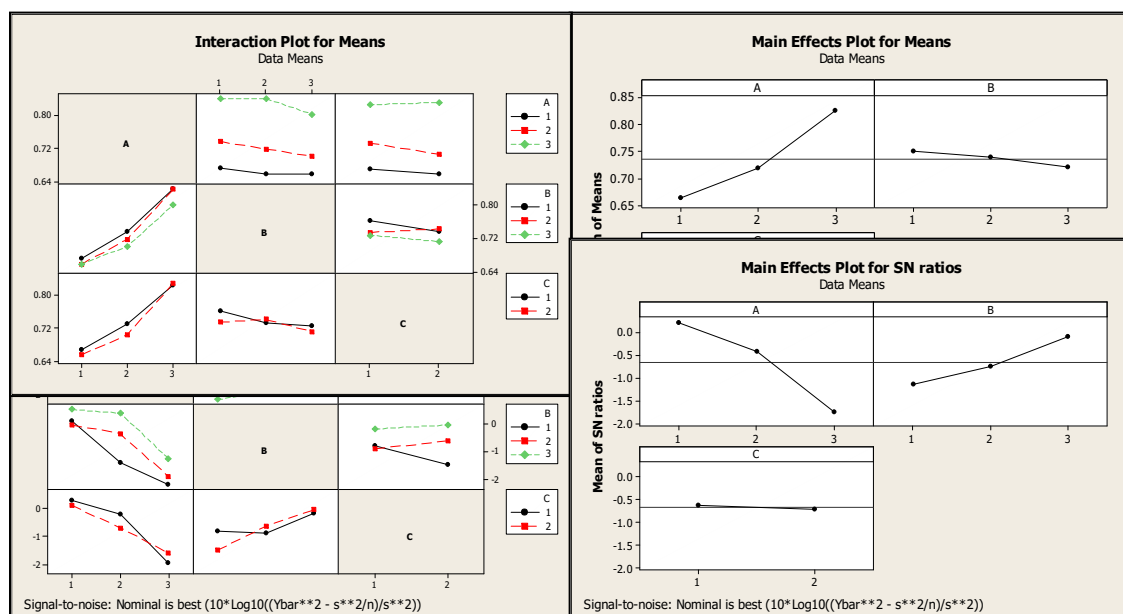
Figure 10: Taguchi analysis when nominal is better; Main Effects and Interaction plots for Means in the top and for S/N ratio in the two bottoms

The (A) factor has large positive slope and A3 has the highest mean (0.83), while A1 is the lowest (0.67). Factor B has negative slope and B1 has the highest (0.75) and B3 is lowest (0.72). Factor C is almost flat which has very little effect on the mean.

A-B interaction clearly has lines diverge strongly. While A-C has small effect and B-C is almost flat. Factor A strongly influences both means and S/N ratio, but in opposite ways; means trend upward (Level 3 highest), but S/N ratio trend downward (Level 1 best). Factor B has small effect on means, noticeable on S/N (Level 3 better). Factor C has negligible effect.

DISCUSSION

Based on the results of Figures (1, 2, 3, 4, 5, 6, 7, 8, 9 and 10) significant differences were observed when pollinating date palms with Red Ghannami pollen. This effect can be attributed to the ability of this pollen source to improve the qualitative and chemical traits of the Khastawi cultivar, as it increased the fruit set percentage, which in turn enhances the yield per palm [26] [27]. The growth, development, and improvement of fruit characteristics are positively reflected in increasing productivity and farmers' income [28] [29].

Therefore, selecting pollen sources that provide abundant pollen grains, such as the Red Ghannami cultivar, which exhibit high viability and efficiency in fertilization and fruit set, is crucial due to their impact on fruit quality traits. Such care should be given equal importance as that of female palms, considering the vital role of pollen grains in influencing both seeds and fruits of the date palm [30] [31] [32]. The significant impact of the traditional hand pollination method using male spadices lies in ensuring full distribution of pollen grains across the female inflorescence by the farmer, which consequently increases fruit set, reduces fruit drop, and leads to significant improvements in both quality and productivity [33] [34] [35]. Repeated pollination further guarantees the complete coverage of all female flowers of the spadix, thereby ensuring increased production through higher fruit set and reduced fruit drop [36]. The benefits of integrating these three factors selection of the most suitable pollen source, appropriate pollination method, and repetition of pollination—lie in their effective role in enhancing the efficiency of pollination in Khastawi date palms. This leads to achieving the highest quality fruits [37] [38]. The findings of this study are in agreement with those reported by Al-Alawi [39] [40] [41] [42] [43] [44] and [45].

CONCLUSIONS AND RECOMMENDATIONS

Based on the study results, the authors conclude the following:

- Pollen source is the dominant influence on outcomes where it consistently shows the largest impact on both means and S/N ratios. In practical terms, prioritizing the level of (A) will yield the biggest gains (or losses) in the measured quality characteristics, regardless of whether you are optimizing for larger-is-better, smaller-is-better, or nominal-is-best objectives.

- Pollination treatment method has a noticeable but smaller effect and the replication number is the least influential. This suggests a design focus on pollen source (primary) with pollination treatment method as a secondary tuning factor, while replication number can be given lower priority or fixed at a level that simplifies experimentation.

- Significant interactions between pollen source and Pollination treatment method, and between pollen source and replication number. Optimization cannot consider A in isolation; the best level for pollen source depends on the level chosen for pollination treatment method (and to a lesser extent replication number).

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