Impact of Growth Regulators on Yield and Fruit Quality of Ferehy Date Palm Cultivar

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Abstract

Date palm (*Phoenix dactylifera* L.) is an important crop in arid regions, providing significant economic and nutritional value. The yield and quality of date fruits can be influenced by various agricultural practices, including the application of plant growth regulators (PGRs). Gibberellic acid (GA3) and CPPU (N-(2-chloro-4-pyridyl)-N-phenylurea), a synthetic cytokinin, are among the growth regulators known to improve fruit size, weight, and overall quality. GA3 and CPPU, both separately and in combination with potassium citrate (45%), were applied to Ferehy date palms to assess their effects on fruit yield and quality. Bunches were sprayed with GA3 (20–80 ppm), CPPU (5–20 ppm), and potassium citrate at two stages after pollination, one and two months post-pollination. The results revealed that the combined application of GA3 and CPPU significantly increased yield, bunch weight, and fruit quality compared to untreated control palms. Specifically, treated bunches showed improvements in fruit weight, diameter, height, flesh percentage, total soluble solids, and total sugars, while seed percentage, total acidity, and crude fiber were reduced. Although both GA3 and CPPU were effective when applied separately, GA3 was more effective in improving all measured parameters. Based on these findings, applying a combination of GA3 at 80 ppm and CPPU at 20 ppm, twice after pollination, is recommended to optimize yield and fruit quality in Ferehy date palms.

Keywords: Ferehy date palm cultivar, post-pollination treatments, plant growth regulators, GA3, CPPU, potassium citrate, yield, fruit quality.

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Introduction

Dates are known for their high nutritional value, primarily due to their abundance of sugars, including both reducing and non-reducing sugars (Hussein, 1977). In addition to their sugar content, dates are rich in essential minerals, which offer various health benefits. These minerals play vital roles in the biosynthesis of larger molecules within plant cells and contribute to important biological processes and human nutrition (Gross *et al*., 1983). Date palm fruits also contain many free amino acids, vitamins, antioxidants, and high percentages of sugars and minerals. Moreover, the seeds contain 5-10% fats, 5-8% proteins, 20-25% fiber, 1-2 % ash and 50- 60% carbohydrates on a dry weight basis (Hussein *et al.*, 1993 and Wrighey, 1995). According to the 2022 Egyptian statistics, the total number of female date palms

15,710,250, with a production of 1,847,629 tons, occupying a total area of 177,102 feddans (2022 Statistics). Plant growth regulators (PGRs) have become essential tools in modern agriculture to enhance crop productivity and quality. Gibberellic acid (GA3), a widely used PGR, is known to improve fruit size and quality by promoting cell division and elongation. It has been shown to increase fruit size, enhance yield, and improve fruit color when applied at the fruit set stage (Peakcock and Beede, 2004). Additionally, GA3 has been reported to decrease seed weight and fruit maturation, while increasing pulp weight, total soluble solids (TSS), and fruit weight (Hussein *et al*., 1993; Benjamin *et al*., 1997). Auxins stimulate rooting, shoot elongation, flowering, and fruiting on thin trees/palms. Cytokinins can promote cell division and root growth while prolonging flower and vegetable storage. also play distinct roles in plant development. Auxins stimulate root development, shoot elongation, flowering, and fruiting in palms. Cytokinins promote cell division and root growth, while also enhancing the storage of flowers and vegetables (Rademacher, 2015; Toungos, 2018). Ethylene generators, on the other hand, facilitate uniform ripening and maturation of fruits (An *et al.*, 2020). Potassium citrate has been recognized for its positive impact on plant growth and development (El-Nasr and Ibrahim, 2011). As a source of potassium, it supports essential processes such as photosynthesis, water regulation, and nutrient transport. Potassium citrate has been shown to promote faster, more robust plant growth, which can lead to higher fruit yield and quality, particularly in date palms **(**Khodair, El-Rahman and Radwan, 2021**)**. Furthermore, potassium and citric acid are known to enhance a plants ability to withstand stressors likedrought, heat, and cold (Tahjib-Ul-Arif *et al.*, 2021). CPPU (N-(2-chloro-4-pyridyl)-N-phenylurea), also known as Sitofex, is a plant growth regulator with cytokinin-like properties. It is well-documented for its ability to stimulate cell division and enhance cell wall integrity. When applied at low concentrations, CPPU promotes fruit growth, reduces fruit drop, increases yield, and improves fruit size and firmness, while delaying maturation (Ennab, 2019; Thakur *et al.*, 2020). In addition to improving fruit yield and quality, PGRs such as GA3, CPPU, NAA, and BAA can be utilized to extend the shelf life of dates without the need for time-consuming and costly postharvest treatments (El-Kosary, 2009; Al-Obeed, 2010). This study aimed to evaluate the effects of GA3 and CPPU on the yield, fruit size, weight, and quality of Ferehy date palms. The goal is to identify optimal practices that enhance both productivity and fruit quality, contributing to improved cultivation techniques for more productive and higher-quality date palms.

Materials and methods

This study was conducted over two consecutive seasons (2022-2023) in a private orchard located in Siwa Oasis, Matruh Governorate, Egypt. The orchard consisted of 30 25-year-old Ferehy date palms planted on sandy loam soil with a spacing of 7.0 meters between trees (86 palms per feddan). The palms were irrigated using well water through a surface irrigation system and were regularly pruned to maintain a

leaf-bunch ratio of 8:1 (Sayed, 2002). The palms were conventionally propagated from offshoots and are known to produceing high-quality fruits.

Each palm was limited to ten female spathes,andartificial ripening was achieved by inserting five pollen strands into each bunch 3-4 days after spathe cracking. To prevent pollen contamination, each bunch was bagged with a paper bag tied at both ends, and a small piece of cotton was inserted to allow proper aeration. The bags were gently shaken to distribute the pollen grains, and were removed one month later (Hussein *et al.,* 1993 and Dammas, 1998).

Horticultural practices, including fertilization and three sprays with micronutrients (Ca, Mg) and potassium citrate during the season, were applied to each palm, following the standard practices for Ferehy palms in the orchard. The application of growth regulators, however, was the variable under investigation.

Table (1): The mechanical, chemical and physical properties of the orchard soil were as follows (Wilde *et al.,* 1985).

Content	Value	Content	Value
Sand %	49.5	OM %	2.9
Silt %	28.0	$CaCO_3$ %	2.2
Clay %	22.5	Total N %	0.07
Texture	Sandy loam	Av. P (ppm)	9.3
pH (1: 2.5 extract)	7.92	Av. K (ppm)	108.0
EC (1: 2.5 extract)	0.94		

Experimental Design and Treatments: The study included 10 different spray treatments, applied to the selected palms as follows:

1- Control (potassium citrate 2g/L)
2- GA_3 at 20 ppm
3- GA_3 at 40 ppm
4- GA_3 at 80 ppm
5- CPPU at 5 ppm
6- CPPU at 10 ppm
7- CPPU at 20 ppm
8- GA_3 at 20 ppm + CPPU at 5 ppm
9- GA_3 at 40 ppm + CPPU at 10 ppm
10- GA_3 at 80 ppm + CPPU at 20 ppm

The experimental used a Randomized Complete Block Design (RCBD) with three replicates (three palms per treatment). Both GA3 and CPPU were sprayed twice: one month and two months after pollination (in the first weeks of April and May). All spray treatments were prepared in water with added potassium citrate (45%) at 2 g/L, and Triton B (0.5 ml/L) was included to facilitate the wetting of GA3 and CPPU. A 10 L/palm dose was applied to each bunch.

Quality assessments of Ferehy date palm

Physical characteristics:

1. **Spathe characteristics:** Girth and length (cm)
2. **Bunch weight:** Average weight per bunch (kg)
3. **Total yield:** Total yield per palm (kg)
4. **Fruit characteristics (assessed by studying 50 randomly picked date fruits per palm):**

- Fruit weight (g) and dimensions (cm)
- Seed and flesh weight (g)
- Edible (flesh) to non-edible (seeds) ratio

Chemical characteristics:

1. **Total soluble solids (TSS%):** Using a conventional hand refractometer
2. **Total, reducing, and non-reducing sugars (%):** According to the volumetric method of Lane and Eynon (1965) and AOAC (2000)
3. **Total acidity (%):** By acid-base titration of the fruit juice against 0.1 N NaOH in the presence of phenolphthalein indicator (AOAC, 2000)
4. **Total crude fiber (% wt/wt):** Calculated by dividing the residue weight (g) by the total sample weight (g), then multiplying by 100 (AOAC, 2000)

Statistical Analysis

The collected data were analyzed statistically using the methods described by Mead *et al.* (1993) and Rangoswamy (1995). Treatment means were compared using the least significant difference (LSD) test at a 5% significance level.

Results

1. Yield per palm and bunch aspects

The data presented in Table 2 clearly indicate that the yield parameters, including yield per palm and bunch weight (kg), as well as the spathe girth and length (cm), significantly improved with the application of GA3 (20–80 ppm) and/or CPPU (5–20 ppm), either alone or in combination. These enhancements were observed in comparison with the control group treated with only potassium citrate. The improvements were proportional to the concentrations of GA3 and CPPU applied. Notably, GA3 was more effective than CPPU, and the combined application of both growth regulators yielded the best results. Specifically, spraying the bunches twice, one and two months after pollination with GA3 at 80 ppm and CPPU at 20 ppm resulted in the highest measurements for these parameters, with consistent findings across both growing seasons.

2. Physical characteristics of the fruits

As shown in Table 3, the application of single or combined sprays with GA3 (20–80 ppm) and CPPU (5–20 ppm) significantly improved several physical characteristics of the fruits. This included increases in fruit weight, fruit dimensions (height and diameter), percentage of fruit flesh, and the ratio of edible to non-edible parts. Additionally, the seed weight percentage was significantly reduced when compared to the control palms, which only received potassium citrate. The degree of improvement was dependent on the concentrations of GA3 and CPPU, with GA3 showing greater effectiveness. Moreover, combined applications of both growth regulators were more beneficial for fruit quality than individual treatments. The best results were observed with GA3 at 80 ppm and CPPU at 20 ppm, applied twice during the growing seasons. These improvements were consistent across both seasons.

3. Chemical characteristics of the fruits

Table 4 indicates that spraying Ferehy date bunches with GA3 (20–80 ppm) and/or CPPU (5–20 ppm), along with potassium citrate, significantly enhanced the chemical characteristics of the fruits. This included increases in total soluble solids (TSS%), as well as reducing, non-reducing, and total sugars. Additionally, the treatments resulted in significant reductions in total acidity and crude fiber when compared to the control palms treated only with potassium citrate. These chemical improvements were more pronounced at higher concentrations of GA3 and CPPU, with GA3 proving to be more effective in improving these traits. The combined application of both growth regulators was notably more beneficial than using either treatment alone. The best results for fruit quality were achieved with GA3 at 80 ppm and CPPU at 20 ppm, applied twice. Conversely, untreated palms exhibited lower fruit quality. These findings were consistent across both growing seasons.

Discussion

Growth regulators play a critical role in managing fruit growth and development. These substances are used not only to control ripening (effectively delaying it) but also to enhance fruit quality, which can significantly boost farmers' income (Kassem *et al*., 2011). A notable growth regulator, Sitofex, has emerged as a powerful tool due to its strong cytokinin activity, which promotes fruit growth even at low concentrations (Ennab, 2019; Thakur *et al.*, 2020). Research indicates that spraying CPPU at concentrations of 5 to 20 ppm can significantly impact on fruit size (Nurhidayati *et al.*, 2022). The effectiveness of this treatment is influenced by various factors, including application methods, the desired response, the developmental stage of the plant at the time of application, and other environmental variables (Nurhidayati *et al.*, 2022). Moreover, the retention percentage of fruits from Zaghloul and Samany date palm cultivars was significantly reduced when treated with GA3, NAA, and CPPU compared to the control group. In contrast, spraying CPPU not only increased bunch weight for

both cultivars but also showed a preference for this treatment over GA3 and NAA (El-Kosary, 2009). Additionally, potassium citrate and citric acid have been recognized for their beneficial effects on fruit quality and development (Tahjib-Ul-Arif *et al.*, 2021). Studies indicate that potassium citrate can enhance fruit size, improve overall plant health, and increase nutrient uptake, potentially leading to better yields (Abdelghany, 2024). When combined with other growth regulators, potassium citrate may offer a synergistic effect, maximizing both fruit quality and farmer revenues (Ahmed and Taha, 2023; Fawaz *et al.*, 2024). The observed improvements in the yield and quality aspects of Ferey date palms as a result of using these PGRs can be attributed to their crucial role in plant development (Rademacher, 2015; Carlos, Lerma and Martínez, 2021; Fahad *et al.*, 2021). Forexample, auxins can stimulate shoot growth, improve fruit set, and promote rooting and flowering. Gibberellic acid (GA3) enhances cellular proliferation, leading to longer stalks and larger flowers and fruits. Similarly, cytokinins cytokinins promote bud initiation, root growth, and prolong the shelf life of plants. Ethylene are known to induce ripening and ensure uniform fruit maturation (An *et al.*, 2020; Carlos, Lerma and Martínez, 2021; Fahad *et al.*, 2021). Several studies have demonstrated the positive effects of GA3 and CPPU on fruit quality. For instance, Al- Obeed (2010), Kassem *et al*. (2011), Abd El- Raheem *et al*. (2013), Ghazzawy (2011), and Khodair (2015) all reported significant improvements in productivity and fruit quality when these plant growth regulators were applied

Conclusions

The application of plant growth regulators, including GA3, CPPU, and potassium citrate, significantly improved the yield and quality of Ferehy date palms. The combined use of GA3 and CPPU, particularly at higher concentrations, enhanced fruit size, weight, and overall quality, as well as increased the proportion of edible flesh and soluble solids. These treatments also resulted in a reduction in seed percentage, acidity, and fiber content. Based on the findings, it is recommended to apply a combination of GA3 at 80 ppm and CPPU at 20 ppm, along with potassium citrate, to optimize both yield and fruit quality in Ferehy date palms.

Table (2): Effect of growth regulators on spathe aspects, bunch weight and yield per palm of Ferehy date palms during 2022 and 2023 seasons

Treatments	Spathe girth (cm)		Spathe length (cm)		Bunch weight (kg.)		Yield per palm (kg.)	
	2022	2023	2022	2023	2022	2023	2022	2023
T_1 - Control	21.0	21.5	44.5	45.0	11.0	11.20	110.0	112.0
T_2 –Spraying GA_3 at 20 ppm	25.0	25.2	51.0	51.8	12.50	12.70	125.0	127.0
T_3 – Spraying GA_3 at 40 ppm	26.8	27.0	53.0	53.5	12.80	13.00	128.0	130.0
T_4 – Spraying GA_3 at 80 ppm	27.0	27.4	54.0	55.0	13.00	13.20	130.0	132.0
T_5 – Spraying CPPU at 5 ppm	22.2	22.5	47.0	48.0	11.57	11.80	115.7	118.0
T_6 – Spraying CPPU at 10 ppm	23.5	24.0	50.5	51.0	12.05	12.30	120.5	123.0
T_7 – Spraying CPPU at 20 ppm	24.8	25.0	51.8	52.2	12.30	12.50	123.0	125.0
T_8 – Spraying GA_3 20 ppm + CPPU at 5 ppm	27.0	27.5	54.0	55.0	13.10	13.50	131.0	135.0
T_9 – Spraying GA_3 40 ppm + CPPU at 10 ppm	28.2	29.0	56.5	58.0	13.90	14.10	139.0	141.0
T_{10} – Spraying GA_3 80 ppm + CPPU at 20 ppm	29.0	29.5	58.5	60.0	14.20	14.50	142.0	145.0
New LSD at 5%	0.4	0.5	0.6	0.7	0.72	0.76	5.5	6.1

Table (3): Effect of growth regulators on physical characteristics of the fruits of Ferehy date palms during 2022 and 2023 seasons

Treatments	Av. Fruit weight (g.)		Av. Fruit height (c.)		Av. Fruit diameter (cm.)		Seed weight %		Fruit flesh %		Flesh/ seed (edible/ non-edible)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
T_1 - Control	4.8	5.0	2.4	2.5	1.3	1.4	20.0	19.5	80.0	80.5	4.0	4.1
T_2 –Spraying GA_3 at 20 ppm	5.5	5.6	3.2	3.3	1.9	2.0	18.1	18.0	81.9	82.0	4.5	4.6
T_3 – Spraying GA_3 at 40 ppm	5.8	5.9	3.4	3.5	2.1	2.2	17.6	17.5	82.4	82.5	4.7	4.7
T_4 – Spraying GA_3 at 80 ppm	6.0	6.2	3.5	3.6	2.2	2.3	17.0	16.8	83.0	83.2	4.9	5.0
T_5 – Spraying CPPU at 5 ppm	5.1	5.3	2.6	2.7	1.5	1.6	19.2	19.0	80.8	81.0	4.2	4.3
T_6 – Spraying CPPU at 10 ppm	5.4	5.5	2.8	2.9	1.7	1.8	18.5	18.2	81.5	81.8	4.4	4.5
T_7 – Spraying CPPU at 20 ppm	5.6	5.7	3.0	3.2	1.9	2.0	18.0	17.8	82.0	82.2	4.6	4.6
T_8 – Spraying GA_3 20 ppm + CPPU at 5 ppm	6.2	6.3	3.5	3.6	2.2	2.3	16.8	16.6	83.2	83.4	5.0	5.1
T_9 – Spraying GA_3 40 ppm + CPPU at 10 ppm	6.6	6.8	3.8	3.9	2.4	2.5	15.5	15.2	84.5	84.8	5.5	5.6
T_{10} – Spraying GA_3 80 ppm + CPPU at 20 ppm	6.8	7.0	4.0	4.1	2.5	2.6	14.0	13.8	86.0	86.2	6.1	6.2
New LSD at 5%	0.4	0.5	0.2	0.3	0.1	0.2	0.4	0.5	0.6	0.7	0.2	0.3

Table (4): Effect of growth regulators on some chemical characteristics of the fruits of Ferehy date palms during 2022 and 2023 seasons

Treatments	TSS%		Total sugars %		Reducing sugars %		Non- reducing sugars %		Total acidity %		Crude fiber %	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
T_1 - Control	66.5	66.0	59.0	58.5	12.0	12.5	47.0	46.0	0.370	0.380	2.20	2.30
T_2 – Spraying GA_3 at 20 ppm	70.2	71.0	63.5	63.8	14.2	14.5	49.3	49.3	0.320	0.310	1.80	1.75
T_3 – Spraying GA_3 at 40 ppm	71.2	71.5	64.2	64.6	15.5	16.0	48.7	48.6	0.300	0.290	1.65	1.60
T_4 – Spraying GA_3 at 80 ppm	72.0	72.5	65.5	66.0	16.0	16.4	49.5	49.6	0.280	0.270	0.60	1.55
T_5 – Spraying CPPU at 5 ppm	67.8	68.0	60.0	60.4	12.8	13.2	47.2	47.2	0.350	0.430	2.00	1.90
T_6 – Spraying CPPU at 10 ppm	68.9	69.2	61.2	61.5	13.4	14.0	47.8	47.5	0.330	0.315	1.90	1.80
T_7 – Spraying CPPU at 20 ppm	70.0	70.8	63.0	63.6	14.0	14.5	49.0	49.1	0.315	0.300	1.88	1.80
T_8 – Spraying GA_3 20 ppm + CPPU at 5 ppm	72.0	72.5	65.8	66.2	16.0	16.6	49.8	49.6	0.290	0.280	1.55	1.45
T_9 – Spraying GA_3 40 ppm + CPPU at 10 ppm	73.0	73.5	66.5	66.8	16.8	17.0	49.7	49.8	0.265	0.260	1.40	1.30
T_{10} – Spraying GA_3 80 ppm + CPPU at 20 ppm	73.8	74.2	67.2	68.0	17.2	17.5	50.0	50.5	0.245	0.240	1.30	1.20
New LSD at 5%	0.8	0.9	0.6	0.5	0.3	0.4	0.1	0.2	0.016	0.017	0.06	0.07

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تأثير منظمات النمو على إنتاجية وجودة ثمار نخيل البلح صنف الفريحي

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[١]معهد بحوث البساتين- مركز البحوث الزراعية – الجيزة - مصر

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[٣]المعمل المركزى للزراعة العضوية – مركز البحوث الزراعية – الجيزة – مصر

الملخص العربي

يُعد نخيل البلح (*Phoenix dactylifera* L.) من المحاصيل الهامة في المناطق الجافة، حيث يُسهم في تحقيق قيمة اقتصادية وغذائية كبيرة. تؤثر العديد من الممارسات الزراعية، بما في ذلك استخدام منظمات النمو النباتية(PGRs) ، على إنتاجية وجودة ثمار البلح. من بين هذه المنظمات، يُعتبر حمض الجبرليك (GA3) والسيتوفكس(CPPU) ، وهو منظم نمو اصطناعي من نوع السايتوكينين، من بين المركبات المعروفة لتحسين حجم الثمار ووزنها وجودتها. خلال موسمي ٢٠٢٢ و٢٠٢٣، تم رش سوباطات نخيل البلح الفريحى مرتين باستخدام الجبرلين بتركيزات تتراوح من ٢٠ إلى ٨٠ جزء في المليون، والسيتوفكس بتركيزات من ٥ إلى ٢٠ جزء في المليون، بالإضافة إلى سترات البوتاسيوم بتركيز ٢ جرام لكل لتر، وذلك بصورة فردية أو مشتركة بعد التلقيح اليدوي بشهر وبشهرين. هدفت الدراسة إلى اختبار التأثيرات الفردية والمشتركة للجبرلين والسيتوفكس وسترات البوتاسيوم على كمية المحصول وجودة ثمار البلح الفريحى. أظهرت النتائج أن التطبيق المشترك للجبرلين والسيتوفكس مع سترات البوتاسيوم أدى إلى زيادة كبيرة في الإنتاجية ووزن السوباطة وجودة الثمار مقارنة بالنخيل غير المعالج. تمثل ذلك في تحسن وزن وأبعاد الثمرة، وزيادة نسبة اللب، والمواد الصلبة الذائبة الكلية، والسكريات، مع انخفاض في نسبة البذور، والحموضة، والألياف الخام. كما تبين أن الجبرلين كان أكثر فعالية من السيتوفكس في تحسين جميع المعايير المقاسة. من خلال هذه النتائج، يمكن تحقيق أقصى استفادة من إنتاجية وجودة ثمار نخيل البلح الفريحى عند رش السوباطات بمزيج من الجبرلين بتركيز ٨٠ جزء في المليون، والسيتوفكس بتركيز ٢٠ جزء في المليون، مع سترات البوتاسيوم مرتين بعد التلقيح اليدوي بشهر وبشهرين.

الكلمات الدالة: نخيل البلح الفريحى، معاملات ما بعد التلقيح، منظمات نمو النبات، حمض الجبرليك (GA3)، السيتوفكس(CPPU) ، سترات البوتاسيوم، الإنتاجية، جودة الثمار.