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RESEARCH ARTICLE

Enhancing 'Barhee' date palm productivity and fruit characteristics using fruit thinning and exogenous treatment with CPPU

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Abstract

The current study was conducted to examine the effects of thinning strands at levels; T_o (no strands shortening), T_1 (shortening the strand length by 10 cm from the terminal tip) and T_2 (shortening the strand length by 20 cm from the terminal tip). The thinning process was carried out four weeks after pollination, along with CPPU(N-(2-Chloro-4-pyridyl)-N'-phenyl urea) spraying at three concentrations C_0 (spraying clusters with distilled water only), C_1 (spraying clusters with CPPU at 5 mg L^{-1}) and C_2 (spraying clusters with CPPU at 10 mg L^{-1}). Treatments were applied during Hababoukand the Kamri stages prior the fruit colour changed, on 27 Barhee palm trees with (22 years old as uniform in vegetative growth as possible) during the 2023-2024 season in a private grove located in Al-Tarmia province, 55 km north of Baghdad. The results showed that thinning process especially by T_2 improved fruit quality, reduced fruits drop, increased bunch weight and yield per palm, accelerated fruit ripening, increased the (TSS), decreased acidity and enhanced the ripening index compared to control, Conversely spraying with CPPU, especially C_2 improved fruit qualities, minimizing fruit drop, increased the weight of the bunch, yield per palm, reduced fruit ripening, TSS, increased acidity consequently decreased ripening index. The combined treatment T_2C_2 produced the most significant improvement in productivity and fruit characteristics.

Keywords: Barhee; CPPU; cytokinin; date palm; fruit thinning; fruit characteristics

Introduction

The date palm tree (*Phoenix dactylifera* L.) holds an important place in Iraq's agricultural and cultural heritage. This tree symbolizes adaptation and resistance in a region where it has thrived for thousands of years. Iraq is considered the cradle of date palm cultivation, with evidence suggesting that the tree has been cultivated since at least 4000 BC in Mesopotamia, where it was an integral part of local economies and diets (1, 2). Historically, Iraq boasted over 33 million palm trees, making it the world's largest producer of dates before the Gulf and Iran-Iraq wars severely impacted the agricultural landscape (3). The decline in tree productivity and spoilage in quality has emphasized the challenges this pivotal crop faces due to conflict, environmental degradation and urban development (4). The Barhee date palm is an important commercial cultivar and it is considered particularly valued for its sweet fruit, which is consumed at both the Khalal (early ripening) and Rutab (ripening) stages. Barhee date palm is primarily cultivated in hot, dry climates and thrives in areas such as Iran, Iraq and the Arabian Gulf (5, 6).

Fruit thinning can dramatically increase development of fruit, yield and fruit features, according to recent studies. Fruit thinning is an important agricultural practice aimed at boosting the aspects and productivity of fruits, especially for cultivars such as Khalas, Barhee and Zaghloul. This technique involved decreasing the length of fruit strands to improve physicochemical traits of fruits (7). Shrinking fruit stands significantly improve several quality parameters, including fruit weight, dimensions, pulp thickness and total soluble solids. Studies have shown that fruit thinning practices can lead to a significant increase in fruit quality by allowing better allocation of nutrients to the remaining fruit. It has been observed that shortening fruit strands (20–30 %) enhanced fruit characteristics such as sugar content and pulp percentage while reducing total acidity (8).

Cytokinins belonging to the phenylurea group are a type of artificial growth regulators that mimic natural cytokinins, which promote cell division and expansion. Unlike natural adenine cytokinins such as kinetin and zeatin, phenylurea cytokinins such as thidiazuron (TDZ) and CPPU, which has several trade names such as CPPU, forchlorofenuron or sitofex, are synthetic compounds that are not found naturally in plants. Diphenylurea, on the other hand, is primarily synthetic but can be found naturally at very low concentrations (9, 10). CPPU is an artificial cytokinin that has drawn interest due to its potential to enhance fruits attributes and growth in a variety of cultivated species, including date palms. Improved qualities of date palm fruits have been associated with its application (11, 12). According to previous study

CPPU improve fruit quality by imitating plant hormones that regulate a few physiological systems (13). When used as a solution spray, it may increase cell growth and division, potentially increasing the size of the fruit. Additionally, it has been shown to lessen over pigmented fruits, giving them a more consistent appearance as they mature. The aim of this experiment was to examine the effects of strand shortening, CPPU spray and their combination on fruit characteristics and yield.

Materials and Methods

This investigation was conducted on 27 Barhee date palm trees, (22 years old) of uniform growth during the 2023-2024 season, in a private orchard located in Al-Tarmia province, 55 km from Baghdad to explore the effect of thinning and CPPU spraying on productivity and fruit quality.

The selected trees were cultivated at 10×10 m and the trees were fertilized with organic manure (cattle waste) in November 2023. Triple super phosphate (45 %) at a rate 1.5 kg for each palm was added in January 2024, nitrogen (46 %) at a rate of 4 kg per palm per year, which was added in four equal monthly doses starting from February until May 2024, a mixture of micro elements (Fe, Cu, Zn and Mn at a rate 300 g/palm) was added in February 2024 (14-16).

All the trees were subjected to the same horticultural practices *viz.*, pruning, pollination, pest management and disease monitoring. Experimental soil sample was taken at deepness (0–60 cm) to investigate the physicochemical features which were evaluated and displayed in Table 1.

Treatments and experimental design

As possible were chosen and put via the following treatments, each of which consisting of three replicates and each treatment represented by one tree as an experimental unit containing 8 bunches within the randomized block design (RCBD) (i.e., nine treatments, three replicates, one tree per replicate = 27 tree). A small spraying motor was used to spray bunches until the run - off stage. Tween 20 was used as a surfactant agent. Two factors were applied in this study, the first factor was thinning strands in three levels: T_o (no strands shortening), T_1 (shortening the strands length by 10 cm from the terminal tip) and T_2(shortening the strands length by 20 cm from the terminal tip). On May 13th 2024, four weeks after pollination the thinning treatment was carried out. The second factor was CPPU (Assay 99.9 %), which involved three concentrations, C_0 (distilled water only), C_1 (spraying the bunches with CPPU at 5mg L^{-1}) and C_2(spraying the bunches with CPPU at 10 mg L^{-1}). The CPPU spray was applied twice: first on May 15th 2024, during the Hababok stage and again on July 19th 2024, at the Kamri stage, prior to fruit color change and transition into the Khalal stage.

Measurements

Fruits physical parameters: To assess the physical characteristics of the fruits in the khalal stage, a sample of thirty fruit was chosen from the pre-selected up strands (3 clusters were selected and 10 strands were chosen from each cluster), as follow:

Fresh weight of fruit, pulp and seed (g): A random sample of fruits was taken and their weight was calculated, then the fruit weight was collected. After the seeds had been removed, the weight of the seed and fruit flesh was measured and then divided by the total number of the fruits.

Fruit drop (%): Ten strands were chosen and tagged from each bunch after five weeks of pollination. The dropping was calculated at the termination of khalal phase in accordance to this equation:

$$\text{Fruit dropping (\%)} = \frac{\text{Number of dropped fruits per bunch}}{\text{Number of total fruits per bunch}} \times 100 \quad (1)$$

Bunch weight (kg bunch^{-1}) and yield per palm (kg palm^{-1}): On September 19th 2024, bunch weight and yield were taken after the fruits had reached the ripening stage and 30 % had turned to the date stage (17).

Dry weight (%) and moisture (%): According to previous studies the fruits dry matter and moisture content has been determined by weighing 10 g of the sliced fruit flesh and placing it in a vacuum oven adjusted at 70 °C until the weight kept constant., the following formula was used (18-20).

$$\text{Moisture (\%)} = \frac{\text{weight before dying - weight after dying}}{\text{weight before dying}} \times 100 \quad (2)$$

$$\text{Dry matter (\%)} = \frac{\text{Average dry weight (g)}}{\text{Average fresh weight (g)}} \times 100 \quad (3)$$

Ripening (%): The percentage of ripe fruits was calculated using the following equationand fruits exhibiting softness over about 25 % of their surface area were classified as ripe (21, 22).

$$\text{Ripe fruits (\%)} = \frac{\text{Ripening fruit number}}{\text{Number of fully coloured fruits bisir stage}} \times 100 \quad (4)$$

Chemical parameters: These indicators were measured after 30 uniform fruits were chosen from the labeled strands in the rutab stage in September. Total and reducing sugars were calculated using previous methodology, nonreducing sugars was estimated by the difference between the percentage total and reducing sugars (23). TSS (%): 10 g of fresh fruit flesh and 30 mL of distilled water was completely crushed together using an electric blender. A portable refractometer was utilized to estimate the fruits TSS after the sample

Table 1. Physical and chemical characteristics of the experimental soils

Soil texture / loam clay										
pH	EC1:1) ds m^{-1}	CEC C.mol.L^{-1}	Organic matter g kg^{-1}	Sand g kg^{-1}	Loam g kg^{-1}	Clay g kg^{-1}	N mg kg^{-1}	P mg g^{-1}	K Mgg^{-1}	Total CaCO3 g kg^{-1}
7.4	7.4	3.25	27.21	18.24	38.3	33.2	28.5	71.32	218.7	161.0

was filtered and droplets of the filtrate were obtained (24). Titratable acidity (%): It was determined in accordance with earlier reports by employing 0.1 N sodium hydroxide and phenolphthalein indicator till the equivalence point was achieved. On the other hand, TSS/Acidity was utilized as ripening index (24).

Statistical analysis

Experimental treatments were subjected and arranged into randomized complete block design (RCBD), according to previous researchers, data were analyzed with GenStat and a least significant difference (LSD) test was used for mean separation at probability of ($p \le 0.05$)by two-way analysis of variance (ANOVA) (25).

Results

Fresh weight of fruit, pulp and seed (g): Results presented in Table 2, show that there is an effect of the thinning process and spraying with CPPU in improving the fruit qualities represented by pulp and fruit weight. The thinning treatment T_2 (shortening strands at a rate of 20 cm from the terminal tip) achieved the highest values reaching (18.78 and 20.01 g) and applying spray with CPPU at (10 mg/L) presented (17.72 and 18.95 g) for the mentioned traits respectively, by comparison to treatment T_0 and C_0 gave the minimum values. On the same way, the interaction between factors showed the similar result that appeared in the individual factors, so that the interaction treatment T_2C_2 gave the highest values (21.82 and 23.04 g) for the mentioned traits respectively, by comparison to the control. Moreover, no significant effect was shown for the individual factors and the interaction in their effect on seed weight.

Dropping (%), weight of the bunch (kg/bunch) and yield/palm (kg/palm): Statistical analysis outputs shown in Table 3 revealed that thinning and spraying with CPPU resulted in a reduction in the fruit drop rate. The thinning treatment with a level of T_2 and spraying with CPPU with a concentration of C_2 gave the minimum drop rate, reaching (4.06 and 5.06 %) sequentially compared to the T_0 and C_0, which gave the highest drop rate, reaching (7.32 and 5.95 %) sequentially. In the same manner, the two-way interaction followed the same trend, with the interaction treatment T_2C_2 giving the lowest drop rate, reaching 3.73 %, by comparison to control (7.88 %). As for the bunch weight and yield weight, the T_1 thinning treatment (shortening strands at a rate of 10 cm from the terminal tip) and the CPPU spraying treatment at a concentration of C_2 achieved the highest bunch weight and yield, reaching (24.31 kg/bunch and 316.1 kg/palm) and (25.01 kg/bunch and 325.3 kg/palm) for both treatments and the two mentioned traits, respectively, compared to the lowest values for treatments T_0 and C_0. With the same strength, the T_1C_2 interaction treatment showed significant superiority over the rest of the interaction treatments, giving bunch weight and yield of (25.97 kg/bunch and 337.7 kg/palm), compared to control which gave (19.51 kg/bunch and 253.7 kg /palm).

Fruit dry weight (%), fruit moisture (%) and fruit ripening (%): From the data shown in Table 4, it appears that the thinning process increased the dry matter and reached the highest percentage in treatment T_2, giving 57.50 % comparison to T_0, which gave 53.83 %. Conversely, spraying with CPPU at concentration C_2 reduced the dry mass to 51.51 % in contrast to C_0, which presented highest percentage of dry mass, reaching 59.74 %. The two-way combination had no notable impact on this feature. As for the moisture content of the fruits, it is noted that the thinning process has taken a different approach, as the thinning process T_2 reduced the moisture content of the fruits, giving 43.66 % in comparison to treatment T_0, which gave the highest moisture content of 46.17 %. Conversely, spraying with CPPU at concentration C_2 achieved the highest moisture content of 49.13 % in comparison to treatment C_0, which gave 40.26 %. The two-way interaction did not show any significant effect. As for the percentage of fruit ripening, it appears from the results of Table 4 that the thinning process accelerated the ripening of the fruits, so that the thinning treatment T_2 gave the highest percentage of ripening, reaching 47.50 % compared to the treatment T_0, which gave the lowest percentage of ripening, reaching 43.96 %. The CPPU behaved differently from the thinning process, as the spraying treatment C_2 reduced the ripening of the fruits, giving a ripening percentage of 41.17 % compared to the treatment C_0, which gave the highest percentage of ripening, reaching 51.64 %. Similarly, the combined treatment T_2C_0 recorded the highest ripening percentage (54.44 %).

Total sugars (%), reducing sugars (%) and non-reducing sugars (%): According to the findings of Table 5 , the thinning process at level T_2 increased total sugars recording 44.71 % in comparison to T_0, which gave 40.41 %, while spraying CPPU showed the opposite effect, as spraying CPPU reduced the percentage of sugars, especially at concentration C_2, to give 41.65 % in comparison to C_0, which exhibited the highest percentage of sugars amounting to 44.43 %. Whereas the combination between the factors studied did not show any significant effect on this percentage. As for the percentage of reducing sugars, the results showed that the thinning process increased the percentage of reducing sugars in the fruits to give the T_2 thinning level the highest percentage of 29.51 % in comparison to T_0, which reached 26.03 %, while spraying with CPPU reduced it to give the C_2 concentration the lowest percentage of 27.18 % compared to the C_0 concentration, which achieved the highest percentage of 29.49 %. The interaction showed a significant effect on this trait, as the T_2C_0 interaction treatment achieved the highest percentage of 31.26 % compared to the lowest percentage at the T_0C_2 which reached 24.39 %. Regarding the effect of the study factors on the percentage of non-reducing sugars, neither the thinning process nor the spraying of CPPU showed any significant effect on this percentage, while the interaction between the two studied factors showed a significant effect and the interaction treatment T_2C_1 achieved the highest percentage, reaching 15.88 %, compared to the lowest percentage in the interaction treatment T_0C_1, which reached 13.52 %.

TSS (%), acidity (%) and TSS/acidity: Outputs observed in Table 6 show the significant effect of the thinning process on increasing the percentage of TSS, reducing acidity and increasing TSS/Acidity. T_2 achieved the best values, reaching (50.98 %, 0.191 % and 283.0) for the mentioned traits respectively, compared to the lowest values in treatment T0, which reached (45.16 %, 0.266 % and 171.9) for the mentioned traits, sequentially. In contrast to the thinning process, spraying CPPU at a concentration of C_2 showed a reduction in the percentage of TSS, an increase in the acidity and a reduction in the TSS/Acidity, which reached (46.87 %, 0.270 % and 176.1) for the mentioned traits, respectively, in contrast to treatment C_0, which gave values of (50.55 %, 0.201 % and 264.1) for the mentioned traits, respectively. The interaction between thinning and CPPU spraying did not show any effect on the TSS, but a significant effect appeared in reducing the acidity in the T_2C_0 treatment, which reached 0.158 %

Table 2. Influence of thinning and CPPU and their interaction on f flesh weight (g), seed weight(g), and fruit weight (g)

Thinning (T)	CPPU(C)			
	C0 = control	C1 =5 mg /L	C2 = 10 mg/L	Mean
Pulp weight (g)				
T0 = (without thinning)	13.30	14.48	15.25	14.34
T1 = Strands shortening 10 cm)	14.05	14.95	16.09	15.03
T2 = Strands shortening 20 cm)	15.49	19.05	21.82	18.78
Mean	14.28	16.16	17.72	
	T	C	T×C	
$p \leq 0.05$	0.17	0.17	0.30	
Seed (g)				
T0 = (without thinning)	1.21	1.21	1.22	1.21
T1 = Strands shortening 10 cm)	1.22	1.23	1.23	1.23
T2 = Strands shortening 20 cm)	1.23	1.23	1.22	1.23
Mean	1.22	1.22	1.22	
	T	C	T×C	
$p \leq 0.05$	n.s	n.s	n.s	
Fruit weight (g)				
T0 = (without thinning)	14.51	15.70	16.48	15.56
T1 = Strands shortening 10 cm)	15.28	16.18	17.32	16.26
T2 = Strands shortening 20 cm)	16.72	20.28	23.04	20.01
Mean	15.50	17.39	18.95	
	T	C	T×C	
$p \leq 0.05$	0.17	0.17	0.30	

Table 3. Influence of thinning and CPPU and their interaction on fruit drop (%), bunch weight (kg/bunch) and yield (kg/palm)

Thinning (T)	CPPU(C)			
	C0 = control	C1 =5 mg /L	C2 = 10 mg/L	Mean
Fruit drop (%)				
T0 = (without thinning)	7.88	7.36	6.71	7.32
T1 = Strands shortening 10 cm)	5.55	5.70	4.73	5.32
T2 = Strands shortening 20 cm)	4.42	4.04	3.73	4.06
Mean	5.95	5.70	5.06	
	T	C	T×C	
$p \leq 0.05$	0.16	0.16	0.28	
Weight of the bunch (kg/bunch)				
T0 = (without thinning)	19.51	20.72	24.58	21.60
T1 = Strands shortening 10 cm)	23.29	23.66	25.97	24.31
T2 = Strands shortening 20 cm)	19.63	22.27	24.50	22.13
Mean	20.81	22.22	25.01	
	T	C	T×C	
$p \leq 0.05$	0.47	0.47	0.82	
yield per palm (kg/ palm)				
T0 = (without thinning)	253.7	269.4	319.6	280.9
T1 = Strands shortening 10 cm)	302.9	307.7	337.7	316.1
T2 = Strands shortening 20 cm)	255.2	289.6	318.5	287.8
Mean	270.6	288.9	325.3	
	T	C	T×C	
$p \leq 0.05$	6.20	6.20	10.74	

Table 4. Influence of thinning and CPPU and their interaction on fruit dry weight (%), fruit moisture content (%) and fruit ripening (%)

Thinning (T)	CPPU(C)			
	C0 = control	C1 =5 mg /L	C2 = 10 mg/L	Mean
Dry weight (%)				
T0 = (without thinning)	58.08	53.89	49.52	53.83
T1 = Strands shortening 10 cm)	59.54	56.39	51.58	55.83
T2 = Strands shortening 20 cm)	61.60	57.47	53.43	57.50
Mean	59.74	55.91	51.51	
	T	C	T×C	
$p \leq 0.05$	0.67	0.67	n.s	
Moisture (%)				
T0 = (without thinning)	41.92	46.11	50.48	46.17
T1 = Strands shortening 10 cm)	40.46	43.61	48.42	44.16
T2 = Strands shortening 20 cm)	38.4	44.09	48.49	43.66
Mean	40.26	44.60	49.13	
	T	C	T×C	
$p \leq 0.05$	0.67	0.67	n.s	
Ripening (%)				
T0 = (without thinning)	46.62	43.50	41.76	43.96
T1 = Strands shortening 10 cm)	53.87	46.37	39.99	46.74
T2 = Strands shortening 20 cm)	54.44	46.30	41.76	47.50
Mean	51.64	45.39	41.17	
	T	C	T×C	
$p \leq 0.05$	0.90	0.90	1.56	

Table 5. Influence of thinning and CPPU and their interaction on fruit total sugars (%), reducing sugars (%) and non-reducing sugars (%)

Thinning (T)	CPPU(C)			
	C0 = control	C1 =5 mg /L	C2 = 10 mg/L	Mean
Total sugars (%)				
T0 = (without thinning)	41.82	39.63	39.77	40.41
T1 = Strands shortening 10 cm)	44.56	42.88	41.92	43.12
T2 = Strands shortening 20 cm)	46.91	43.96	43.27	44.71
Mean	44.43	42.16	41.65	
	T	C	T×C	
$p \leq 0.05$	0.87	0.87	n.s	
Reducing sugars(%)				
T0 = (without thinning)	27.58	26.11	24.39	26.03
T1 = Strands shortening 10 cm)	29.63	28.23	27.95	28.60
T2 = Strands shortening 20 cm)	31.26	28.07	29.21	29.51
Mean	29.49	27.47	27.18	
	T	C	T×C	
$p \leq 0.05$	0.37	0.37	0.64	
Non-reducing sugars (%)				
T0 = (without thinning)	14.23	13.52	15.38	14.38
T1 = Strands shortening 10 cm)	14.92	14.65	13.97	14.52
T2 = Strands shortening 20 cm)	15.65	15.88	14.05	15.19
Mean	14.93	14.68	14.47	
	T	C	T×C	
$p \leq 0.05$	n.s	n.s	1.49	

Table 6. Influence of thinning and CPPU and their interaction on TSS (%), acidity (%) and TSS /acidity

Thinning (T)	CPPU(C)			
	C0 = control	C1 =5 mg /L	C2 = 10 mg/L	Mean
TSS (%)				
T0 = (without thinning)	46.95	44.90	43.62	45.16
T1 = Strands shortening 10 cm)	51.98	47.36	46.92	48.75
T2 = Strands shortening 20 cm)	52.71	50.18	50.06	50.98
Mean	50.55	47.48	46.87	
	T	C	T×C	
$p \leq 0.05$	0.85	0.85	n.s	
Acidity(%)				
T0 = (without thinning)	0.241	0.265	0.293	0.266
T1 = Strands shortening 10 cm)	0.205	0.215	0.270	0.230
T2 = Strands shortening 20 cm)	0.158	0.170	0.246	0.191
Mean	0.201	0.216	0.270	
	T	C	T×C	
$p \leq 0.05$	0.010	0.010	0.017	
TSS / Acidity				
T0 = (without thinning)	196.2	170.6	149.0	171.9
T1 = Strands shortening 10 cm)	257.4	224.6	174.8	218.9
T2 = Strands shortening 20 cm	338.7	305.7	204.5	283.0
Mean	264.1	233.6	176.1	
	T	C	T×C	
$p \leq 0.05$	14.15	14.15	24.51	

compared to the lowest acidity in the T_0C_2 interaction treatment, which reached 0.293 %. The T_2C_0 interaction treatment also showed a significant effect in raising the TSS/Acidity, achieving the highest value reached 338.7, in comparison to T_0C_2 reached 149.0.

Discussion

From the results shown in the Tables (2-6), it is clear that thinning the bunches by shortening the length of the strands by (10 and 20 cm from the terminal tip) has improved the physical characteristics of the fruits, represented by the length of the fruit, fruit diameter, shape index, flesh fruit weight and total fruit weight, which included reducing the number of fruits in the bunches, which helps to balance the relationship between the source (leaves) and the sink (fruits). Thus, the thinning process reduces the number of fruits competing for carbohydrates and available nutrients, which improves the distribution of resources produced by the vegetative group through the process of photosynthesis on the remaining fruits, which improves the characteristics of the fruit, which ultimately increases the weight of the fruit. Therefore, the thinning process improves the quality of the crop by promoting fruit enlargement, despite the decrease in the total weight of the crop at times, which leads to an increase in the marketable crop (7, 26-28), Thus, reducing competition between fruits for nutrients and carbohydrates allows more elements and metabolic products to be available to the remaining fruits, which supports their better growth and thus reduces their fall by enhancing their stability (29, 30) . The increased ripening observed due to thinning can be explained by to the improvement of the enzyme pathways by re-balancing the source and sink dynamics, which enhances the transformation of sugars by the existing enzymes, including the invertase enzyme and increases the softness of the fruit by the cellulase enzyme, thus improving the efficiency of ripening and the quality of the marketable fruit. Therefore, the high activity of the enzymes of the remaining fruit after the thinning process is positively related to the early ripening of the fruit (31, 32). These results are consistent with previous studies on date palm cv. Saidy and Hellawi respectively (33-35).

The increase in physical characteristics of the fruit caused by the spraying with CPPU may be a result of several main mechanisms, including that it stimulates cell division and expansion, which contributes significantly to increasing the size and growth of the fruit. In addition, spraying the fruit makes it a place to attract and enhance the movement of carbohydrates by reducing its storage in the leaves and increasing the content of soluble sugars and starch in the fruit, which causes its accumulation and thus supports the fruit morphogenesis, in addition to its effect on the regulation and transfer of nutrients and hormonal regulation processes (36, 37). Developed fruits are considered effective metabolic sinks, which lead to the cell wall responding to turgor pressure, which results in a large penetration of water into the cell due to the high negativity of the water potential and the high osmotic potential. As a result, the cells swell, which work to dilute sugars and total soluble solids. The delay in fruit ripening resulting from spraying with CPPU may be attributed to its inhibition of the activity of enzymes such as invertase and cellulase, which stimulate the conversion of sucrose into reducing sugars (glucose and fructose), this leads to maintaining higher levels of sucrose in the fruit, which delays the structural changes of sugars associated with ripening (38, 39).

Conclusion

Based on the findings of this study, the thinning process, which involved shortening the strand length by 20 cm from the terminal tip, improved the quality of the fruit, reduced the number of fruits that fell off and increased the weight of the bunch, the yield per palm and the speed at which the fruit ripens. It also raised the TSS and lowered the acidity, as well as improved the ripening index, on the other hand, spraying with CPPU, particularly (10 mg/L), enhanced fruit qualities, decreased fruit drop, increased bunch harvest, harvested per palm, reduced fruit ripening, TSS, increased acidity which in turn decreased ripening index . The combined treatment (shortening the strand length by 20 cm from the terminal tip + CPPU (10 mg /L) caused excellent effect of morphological and biochemical attributes of dates.

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Authors' contributions

MJH carried out the materials and methods writing and preparation of the original manuscript. MJH and THRAF were responsible for writing, review and editing and completed the statistical analysis and discussion of the results. THRAF also assisted with manuscript draft correction and coordination. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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