

Effect of a Mechanical Pollination on Quality of "Zaghloul" Date-Palm Fruits During Cold Storage

¹Ibrahim Yehia and ²Zeinab A. Zaki

¹Agricultural Engineering Research Institute, Agricultural Research Centre, Giza, Egypt

²Horticulture Research Institute, Agricultural Research Centre, Giza, Egypt

Abstract: The aim of this investigation was to study some mechanical-pollination factors affecting the machine performance and quality of "Zaghloul" date-palm fruits during cold storage conditions ($0\pm 1^{\circ}\text{C}$ with RH. 85-90%). The effect factors of pollination-device such as: carrying materials of flour, starch, bran, "flour + bran" with ratio 1: 1 and "flour + bran" with ratio 2: 1, air speed ranged between 1.5 - 1.8 m/s and times number of pollination operation on fruit set, bunch mass (bunch weight), fruit mass (fruit weight) and machine performance-rate were investigated. Fruit characteristics weight loss, decay, firmness, total soluble solids content (TSS), total acidity (TA), TSS: acidity ratio and total tannins were evaluated during storage period. The obtained results revealed that the maximum fruit-set of 71.6 % was obtained at air speed of 1.8 m/s using the tested pollination-device three time and carrying material flour + bran with ratio 1:1. Meanwhile, the minimum fruit-set of 59.6 % was obtained at air speed of 1.5 m/s using the tested pollination-device one time and flour carrying-material. Whereas, the fruit set was about 52.3 % by using manual pollination method. Date fruits treated with three-times pollination of and air speed of 1.8 m/s were more able to prevent weight-loss percent of 0.4 and 0.3 % compared with other treatments and control which recorded the highest weight loss of 4.4 and 4.3 % during the 2018 and 2019 seasons, respectively. The maximum decay values of 23.9 and 26.2 % were obtained at first and second seasons of 2018 and 2019, respectively by using pollination machine one time at air speed of 1.5 m/s and cold-storage duration of 60 day. Meanwhile, the minimum decay values of 4.9 and 7.2 % were obtained at first and second seasons, respectively by using pollination machine three times at air speed of 1.8 m/s and cold-storage duration of 15 days.

Key words: Date palm • Mechanical pollinations • Postharvest • Fruit quality • Cold storage

INTRODUCTION

Date palms are considered one of the oldest trees known to ancient people as a source of food. Egypt is considered one of the greatest countries in palm-date production in the world. The total production of date fruits in Egypt amounted to 1, 501, 799 tons/year [1]. In Egypt there many cultivars such as "Zaghloul", "Samany", "Halaway" and "Hayany" are grown in different regions. These cultivars are the earliest ripening varieties of soft- date grown in Egypt. "Zaghloul" date is the most important commercial cultivar in Egypt and highly demanded in the Arab markets [2]. The process of storing dates is necessary to market demands, to increase the marketing period longer than normal season and to obtain a high profit and the optimum temperature to store

the fruits of dates is $0 - 4^{\circ}\text{C}$ and relative humidity is 85-90% to be stored for a month depending on the cultivar [3, 4].

Date palm yield and fruit quality are mostly dependent on cultivar, pollination, fertilization and water relations [5, 6]. Zaghloul cultivar is usually harvested and consumed at Khalal stage when fruits reach full maturity and are crunchy and red in color.

Recently the fruit growers are not interested in increasing the date palm plantations due to problems of pollination, thinning and harvesting. All of these practices are still carried out manually, which consume a lot of time and cost besides the danger of palm climbing [7].

Pollination and thinning are critical processes in the date palm production chain that affects availability of assimilating, fruit development, quality and yield beside

regulates tree yearly bearing [8]. Commercial date-palm production necessitates artificial pollination which ensures enough fruit-setting dioeciously species and reduces the number of required male-palms. Artificial pollination could be performed by using a mechanized device. The most common pollination technique is to cut the strands of male flowers from a freshly opened male spathe. Then, 5- 10 of these male strands were placed length wise with an inverted position between the strands of the female.

Inflorescence and tie the pollinated female cluster 5 to 7 cm from the outer end with a strip torn from a palm leaflet [9]. So, the success of pollination is dependent on environmental factors such as wind and rainfall. Moreover, this traditional or manual-pollination method requires the availability of large number of male spathes that sometime are not available, especially for early-flowering season cultivars [10]. The male/female ratio in modern plantations is about 1:50 (2%). Furthermore, traditional pollination method is a labor-intensive process resulting in high labor costs [11].

Mousa and Eliwa [12] found that the mechanical pollination of "Hiyani" palm-tree gave high fruit set and total yield comparing to manual method. Awady *et al.* [13] designed of a pushed pollination-machine and tested it with some designs of pollination devices. The results showed that, the best system consisted of pollination device with fan blower. It gave a maximum reach of 75 cm and lateral spread of 60 cm. Yehia [15] studied the design and operation factors of the pushed pollination-machine and concluded that the average machine-productivity was 33 palm tree/h. Awady [16] designed, constructed and evaluated a portable machine for pollination of date palm-trees. The main results were: (1) the average machine productivity was 21 palm trees /h, (2) pollination cost for the designed machine was 0.15 LE/palm trees, whereas, the pollination cost by a traditional method was 2.5 LE/palm tree. Awady *et al.* [17] designed, constructed and evaluated a self-propelled machine for pollination of date palm trees. The authors concluded that: (1) the average machine productivity was 10 palm trees /h and (2) pollination cost for the designed machine was 0.74 LE/palm trees, whereas, the pollination cost by a traditional method was 2.5 LE/palm tree. Yehia [18] designed and evaluated a pollination device for palm trees. The data showed the best conditions which gave the suitable performance were carried material of "flour + fine bran" with ratio of 1 : 1, air speed of 1.8 m/s and quantity of mixture inside the hopper 50 - 100 g (all sizes). These

gave a maximum throw of 100 cm, lateral spread of 40 cm and mixture discharge of 0.3 - 0.33 g/s. Moreover, the highest fruit sets of 64.2 and 100 % were obtained by using designed pollinator one and three times, respectively. Whereas, the fruit set was about 51.2 % by using manual pollination method.

Awad [19] studied pollen-grain water suspension spray at different concentrations on fruit set, yield and quality for "Khenazy" date-palm cultivar. Fruit setting was significantly higher in the spray pollination than in the traditional pollination. Spray pollination at the concentration of 1.5 or 2.0 g/l gave higher fruit setting than the application at 0.5 g/l. Both of bunch weight and total yield per tree were significantly higher in spray than in traditional pollination. Fruit diameter was significantly higher in the traditional pollination than in spray pollination. Fruit length was significantly higher in the traditional pollination than in all other treatments. TSS, acidity, vitamin C, total phenols and soluble tannins concentrations of fruit were not significantly affected by any of the pollination treatments at both the bisir and the rutab stages.

Cold storage delayed fruit ripening and extended the shelf life of "Barhee" dates compared with storing at ambient condition [20]. Shimim *et al.* [21] studied the effect of hot water with temperatures of 40, 50 and 60°C on fruit quality during storing ripened dates at 30 ±50°C for 3 months. The optimum hot-water temperature was 50°C which gave firmness values of 2.3 and 1.8 g/cm² and TSS values of 62.98 and 54.39 for "Hilawi" and "Khud Ravi" date-palm cultivars, respectively. Zeinab *et al.* [22] studied the effect of cold-storage period on "Zaghloul" date-palm fruits quality and they found that loss weight-loss values were 0, 15.89, 17.04, 23.87 and 28.08 %, decay values were 0, 14.25, 20.14, 21.79 and 37.37 %, firmness values of 17.5, 17.0, 16.73, 14.8 and 12.33 lb/inch², TSS values of 10.3, 10.8, 11.07, 11.43 and 10.53 %, acidity values of 0.37, 0.37, 0.43, 0.33 and 1.27 and tannins values of 3.33, 2.2, 1.23, 1.47 and 1.53 mg/g for cold-durations of 0, 15, 30, 45 days, respectively at season of 2015. El-Dengawy *et al.* [23] studied the effect of cold-storage period on "Hyani" date-palm fruits quality and found that loss weight-loss values were 1.38, 1.81, 3.08 and 1.40 %, decay values were 0, 0, 0 and 56.7 %, firmness values of 16.4, 16.3, 13.6 and 10.4 lb/inch² and TSS values of 30.1, 37.8, 38.5 and 40.0 % and for cold-durations of 0, 15, 30, 45 days, respectively at season of 2018.

The objectives of the present investigation are the following:

- Evaluating the effect of mechanical pollination parameters (carrying materials, air speeds and times number of pollination operation) on fruit set, bunch mass (bunch weight), fruit mass (fruit weight) and machine performance-rate for “Zaghloul” date-palm fruits.
- Studying the effect of previous mechanical pollination parameters and cold-storage duration on quality of “Zaghloul” date-palm fruits.

MATERIALS AND METHODS

Materials

Pollination Device: The tested pollination-device consists of fan fixed on small electrical motor of 12 volt that operates by a dry battery, pollination grains conical-hopper, a vibrated plastic roller (feeder) that moves by second small motor of 12 volt and conical tubes [18]. The pollination grains drops from the bottom of the hopper around the plastic roller on the fan and the fan air throws them to palm tree (Fig. 1).

For field experiment, the above mentioned pollination-device was mounted on the telescopic holder of the previously developed portable pollination machine [16]. The portable pollination machine consists of 4-arm stand with width of 200 cm and 20 cm height, five telescopic-tubes and pollination device. The total mass of the machine is about 20 kg with width of 2 m, minimum length of 2 m and maximum length of 14 m (Fig. 2).

Carrying Materials: The densities of flour, starch, bran, "flour + bran" with weight ratio of 1:1 and "flour + bran" with ratio of 2: 1 were 0.54, 0.47, 0.39, 0.41 and 0.42 g/cm³.

Methods

Experimental Soil and Palm Conditions: The field experiments were carried out in a private farm in Sharkiea Governorate in seasons 2018 or 2019. The conditions of the farm are as follows: (a) soil type: sandy silt, (b) palm tree variety: Zaghloul, (c) trees spacing: 4 - 9 m, (d) rows spacing: 6 m, (e) palm tree height: 7 - 14 m, (f) Number of bunches per tree: 10 - 14 bunch/tree.

All mechanical-pollination treatments were replicated five times (five trees) to give more reliable averages.

Studied Parameters

Mechanical-Pollination Parameters

Carrying Materials: The tested carrying materials were flour, starch, bran, flour + bran with ratio 1: 1 and flour + bran with ratio 2: 1.

Air Speed: The tested air speeds were 1.5, 1.6 and 1.8 m/s.

Times Number of Pollination Operation: The tested Times number of pollination operation were one and two and three.

Number of treatments = 5 x 3 x 3 = 45 date-palm trees.

Number of replicates = 5 x 3 x 3 x 5 = 225 date-palm trees.

Cold-Storage Conditions and Parameters: Date palm fruits cv. "Zaghloul" were harvested at mid-September during two successive seasons of 2018 or 2019. Fruits were harvested at maturity stage from all tested mechanical-pollination date-palm trees. Fruits were uniform in size, appearance, free from visible physical and pathological defects as possible. Fruits were thoroughly washed with chlorine (1cm³/liter) for 3-5 minutes as sanitizing agents for inhibiting micro-spoilage then washed with tap water only and left to dry completely aerobically [24]. The fruits were packed in carton boxes with size about 3 kg and storage at 0 ± 1°C with 85 - 90 % relative humidity for 60 days. Cold-storage durations of 0, 15, 30, 45 and 60 day were tested. All cold-storage treatments were replicated three times to give more reliable averages and each replicate consisted of 3 fruit clusters. Fruit quality measurements were assessed after storage at 0 ± 1°C for each storage period.

Calculations

Mechanical- Pollination Calculations

Performance Rate of Pollination Machine:

Performance rate (tree/h) = (60 x 60) / Total time (s) according to Awady *et al.* [13].

where: Total time = Moving time among trees + Ascending time + Descending time + Pollination time + Filling time of pollination hopper + Rotating time + Repairs time

Fruit Set (%): Fruit set was calculated by the following equation according to Eliwa, *et al.* [14]:

Fruit set% = Total No. of fruits per bunch / Total No. of flower per bunch x 100

Cold-Storage Calculations

Weight Loss (%): Fruits were weighted before and after an interval of 15 days for a total cold-storage period of 60 days. The fruit weight loss percent was calculated by the following equation according to Vicente *et al.* [25]:

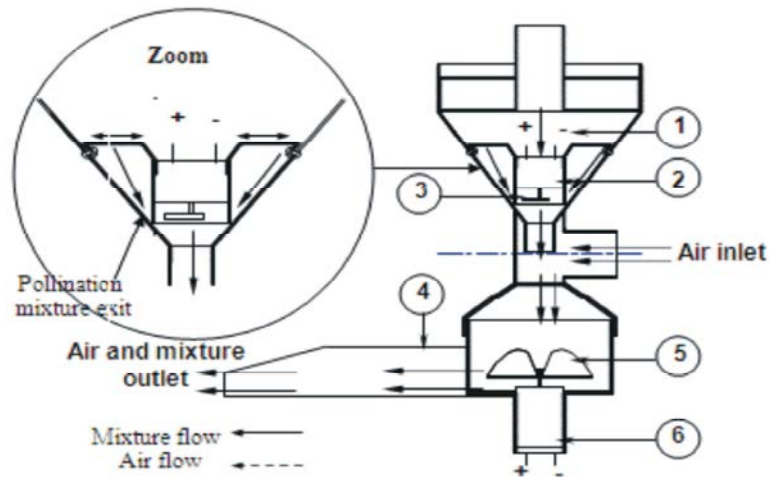


Fig. 1: Section of pollination device of palm tree [18]

(1) pollination-grain hopper, (2) vibrated plastic-roller and 12 volt electrical motor, (3) eccentric mass, (4) conical tube, (5) fan and (6) 12 volt electrical motor

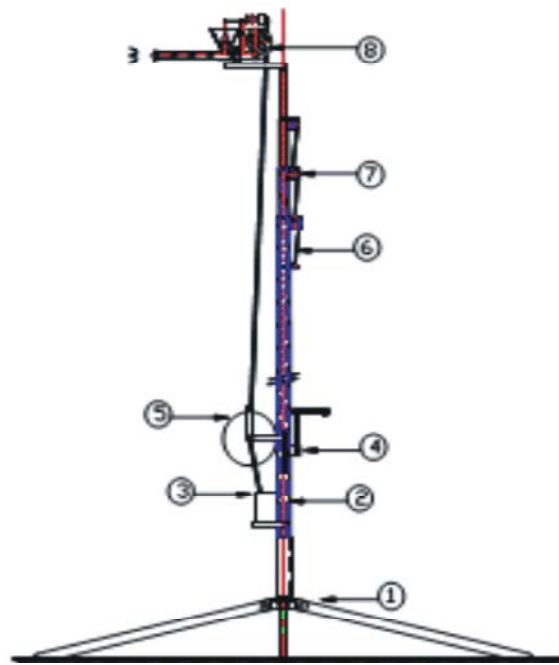


Fig. 2: Sketch of the portable pollination-machine [16]

(1) 4-arm stand, (2) 5-telescopic tubes, (3) 12-volt battery, (4) manual pulley, (5) electrical-wire pulley, (6) steel wire, (7) steel-wire roller and (8) pollination device.

$$\text{Fruit weight loss, \%} = (W_1 - W_2) / W_1 \times 100$$

where: W_1 = weight of sample at first interval and W_2 = weight of sample at second interval.

Decay (%): Decay percentage was calculated as follows:

$$\text{Decay (\%)} = a / b \times 100$$

where: a = Number of decayed fruits at time of sampling.
b = Initial fruit number.

Firmness (g/cm^2): Fruit firmness was recorded by Lira texture analyzer instrument using a penetrating cylinder of 1 mm of diameter, to a constant distance (3 and 5 mm) inside the fruits pulp and by a constant speed 2 mm per sec. and the peak of resistance was recorded per g.

Total Soluble Solids (TSS) Percent: Total soluble solids percent (TSS, as Brix) was measured for tested date-palm fruit juice using digital hand refractometer (Model Palette, PR-32, Atago).

Total Acidity Percent: Total acidity-percent was expressed as malic acid and determined by titrating 5 ml juice with 0.1 N sodium hydroxide using phenolphthalein as an indicator.

Total Soluble Solids / Total Acidity Ratio: This ratio was calculated by dividing TSS (%) by total acidity (%), as the methods described by A.O.A.C. [26].

Total Tannins Content: Total tannins were estimated as mg per gm fresh weight due to the method described by A.O.A.C. [26].

Statistical Analysis: The obtained data were statistically analyzed as a factorial Randomized Complete Block Design with two factors (factor A: Air speed treatments and factor B: storage period) by analysis of variance (ANOVA) using Statistical Analysis System (Co Stat) program. The means of treatments were compared using LSD at 0.05 according to Snedecor and Cochran [27] in the two seasons of study.

RESULTS AND DISCUSSION

Mechanical Pollination

Effect of Pollination Device Parameters on Pollination-mixture Discharge and Throw: The best conditions which gave the best performance of pollination device were carried material of "flour + bran" with ratio of 1: 1, air speed of 1.8 m/s and quantity of mixture inside the hopper of 50-100 g (all sizes). It gave a maximum advance of 100 cm, lateral spread of 40 cm and mixture discharge of 0.3-0.33 g/s.

Effect of Pollination Device Parameters on Fruit Set: Fig. 3 shows that the maximum fruit-set of 71.6 % was obtained at air speed of 1.8 m/s using the tested pollination-device three time and carrying material "flour + bran" with ratio 1 : 1. Meanwhile, the minimum fruit-set of 59.6 % was obtained at air speed of 1.5 m/s using the tested pollination-device one time and flour carrying-material. Whereas, the fruit set was about 52.3 % by using manual pollination method.

The increasing of fruit set by increasing air speed is due to increasing the throw and penetration of pollination mixture inside the palm-tree head.

Effect of Pollination Device Parameters on Bunch Mass (Bunch Weight): Fig. 4 shows that the maximum bunch- mass range of 21.1-22.8 kg was obtained at air-speed range of 1.5 - 1.8 m/s using the tested pollination-device three time and carrying material "flour + bran" with ratio 1 : 1. Meanwhile, the minimum bunch- mass range of 20.1 – 21 kg was obtained at air-speed range of 1.5 - 1.8 m/s using the tested pollination-device one time and flour carrying-material. Whereas, the bunch mass was 18.1 kg by using manual pollination method.

The increasing of bunch mass by increasing air speed is due to increasing fruit set and number of fruit per bunch.

Effect of Pollination Device Parameters on Fruit Mass (Fruit Weight): Fig. (5) shows that the means fruit- mass range of 21.96, 21.92, 21.89, 21.86 and 21.93 g was obtained with pollination with flour, starch, bran, "flour + bran" with ratio 1 : 1 and "flour + bran" with ratio 2: 1, respectively at all tested air-speeds pollination numbers. Meanwhile, the means fruit- mass range of 21.95, 21.91 and 21.87 g were obtained by using pollination device one, two and three times respectively at all tested air-speeds and carrying-materials whereas, the fruit mass was 21.9 g by using manual pollination method.

Moving, Ascending, Descending, Pollination, Rotating, Repairing and Hopper Filling Times and Machine Performance-Rate: The moving, ascending, descending, pollination, rotating, repairing and hopper filling time per tree were 2 – 6, 3 – 7, 4 – 7, 65 –130, 5 – 6, 3.6 and 15 - 20 s. Meanwhile, the average of machine performance was about 30 tree/h (about 240 tree/day).

Operation Cost of Using the Designed Pollination-Device: The operation cost of pollination using the tested portable pollination-machine was about 0.97 LE/palm tree for one time, whereas the manual pollination cost is about 25 LE/palm tree.

Cold Storage of "Zaghloul" Date-Palm Fruits: Effect of Pollination-device Parameters and Cold-storage Duration on Weight-loss Percent: Table (1) showed that weight-loss percent significantly decreased by increasing air speed and times number of pollination operation.

Moreover it was found that averages of weight loss at first season of 2018 of 0, 2.0, 3.3, 6.5 and 13.9 % were obtained at storage durations of 0, 15, 30, 45 and 60 day, respectively at all tested air-speeds and times number of pollination operation. Meanwhile, the averages weight

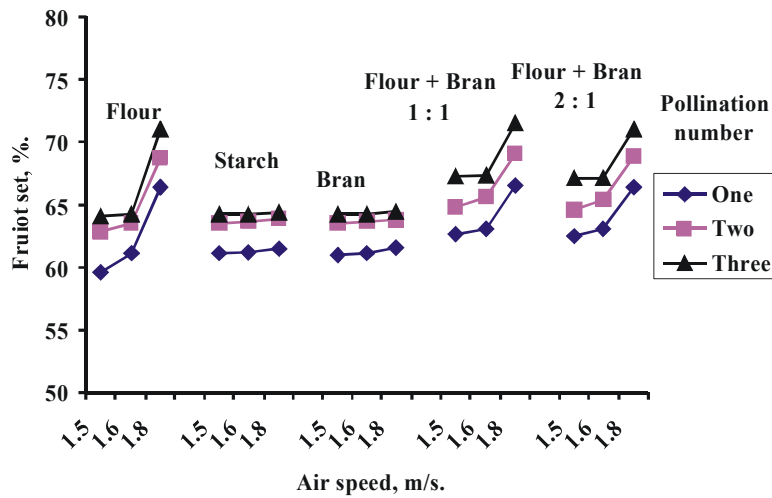


Fig. 3: Effect of air speed, carrying material and number of pollination on fruit set of “Zaghloul” date-palm

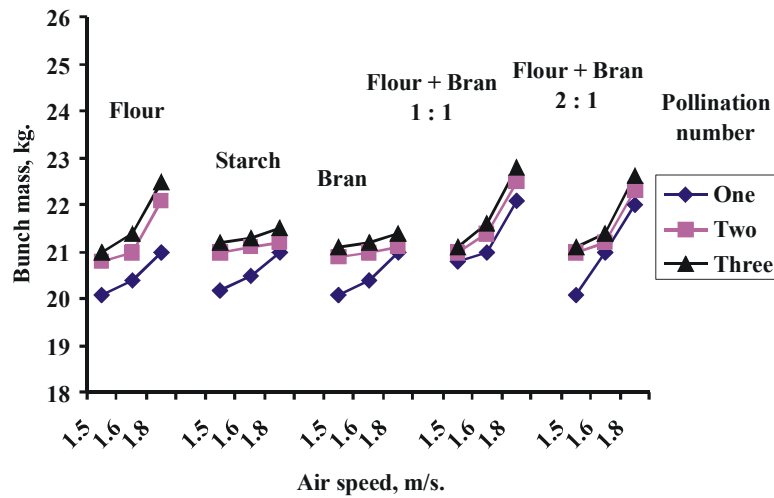


Fig. 4: Effect of air speed, carrying material and number of pollination on bunch mass of “Zaghloul” date-palm

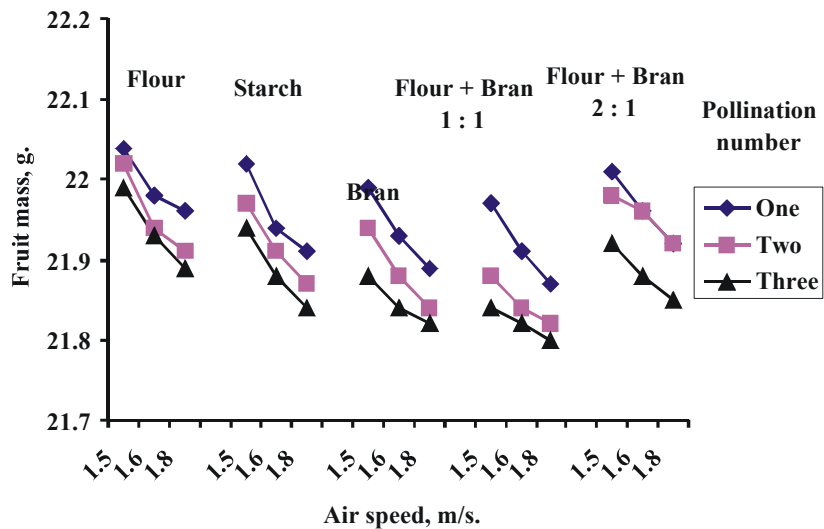


Fig. 5: Effect of air speed, carrying material and number of pollination on fruit mass of “Zaghloul” date-palm

Table 1: Effect of air speed and times number of pollination on weight loss percent of “Zaghloul” date-palm fruits under cold storage during seasons of 2018 and 2019

		Weight loss (%)					
		Storage duration (day)					
Number of pollination	Air speed (m/s)	0	15	30	45	60	Mean
Season 2018							
Control (manual pollination)		0.00	4.40	6.80	10.20	18.00	7.90
Mechanical one time	1.5	0.00	3.20	5.40	8.80	16.60	6.80
	1.6	0.00	2.30	4.20	7.50	15.10	5.80
	1.8	0.00	1.50	3.10	5.40	12.60	4.50
Mechanical two time	1.5	0.00	2.40	3.40	6.80	14.50	5.40
	1.6	0.00	2.10	3.10	6.60	14.00	5.20
	1.8	0.00	1.60	2.20	5.10	12.20	4.20
Mechanical three time	1.5	0.00	1.30	2.10	5.40	12.70	4.30
	1.6	0.00	0.60	1.80	4.80	11.80	3.80
	1.8	0.00	0.40	1.30	4.70	11.20	3.50
Mean		0.00	2.00	3.30	6.50	13.90	
LSD at 5%		A = 0.1		B = 0.1		A*B = 0.2	
Season 2019							
Control (manual pollination)		0.00	4.30	6.40	10.10	14.90	7.10
Mechanical one time	1.5	0.00	3.10	5.20	8.90	13.70	6.20
	1.6	0.00	2.20	4.10	7.70	12.50	5.30
	1.8	0.00	1.40	2.10	5.80	10.60	4.00
Mechanical two time	1.5	0.00	2.30	3.20	7.00	11.70	4.80
	1.6	0.00	2.00	3.20	6.90	11.70	4.80
	1.8	0.00	1.50	2.00	5.60	10.40	3.90
Mechanical three time	1.5	0.00	1.20	2.10	5.70	10.50	3.90
	1.6	0.00	0.50	1.80	5.50	10.30	3.60
	1.8	0.00	0.30	1.60	5.20	9.10	3.20
Mean		0.00	1.90	3.20	6.80	11.50	
LSD at 5%		A = 0.3		B = 0.2		A*B = 0.5	

loss at second season of 2019 of 0, 1.9, 3.2, 6.8 and 11.5 % were obtained at storage durations of 0, 15, 30, 45 and 60 day, respectively at all tested air-speeds and times number of pollination operation.

It was found that fruit weight loss was significantly coincided with the increase of storage duration at all treatments under current investigation. These results were in a partially harmony with the results obtained by Zeinab *et al.* [21] on “Zaghloul” date-palm fruits. They found that fruit weight loss was significantly coincided with the increase of storage duration at all postharvest treatments.

Furthermore, the results showed that the averages of weight loss at first season of 2018 of 5.7, 4.9 and 3.9 % and at second season of 2019 of 5.2, 4.5 and 3.6 % were obtained by using the tested pollination-machine one, two and three times, respectively and at all tested air-speeds. Also, it was found that the averages of weight loss at first season of 2018 of 5.5, 4.9 and 4.1 % and at second season of 2019 of 5.0, 4.6 and 3.7 % were obtained

at air speeds of 1.3, 1.5 and 1.8 m/s, respectively and at all tested storage-durations and numbers of pollination. The decreasing of weight loss by increasing air speed and number of pollination might be due to decreasing weight of date-palm fruits.

Date fruits which treated with three-times pollination of and air speed of 1.8 m/s were more able to reduce weight-loss percent of 0.4 and 0.3 % compared with the other treatments and control which recorded the highest weight loss of 4.4 and 4.3 % during the 2018 and 2019 seasons, respectively.

The effect of the interaction indicated that after 60 days of storage, the least significant decrease in fruits was recorded by air-speeds of 1.8 and three- times number of pollination operation compared with the manual pollinations (control) during the 1st and 2nd seasons.

The decreasing of weight loss by increasing air speed and number of pollination due to decreasing weight of date-palm fruits.

Table 2: Effect of air speed and times number of pollination on decay percent of “Zaghloul” date-palm fruits under cold storage during seasons of 2018 and 2019

		Decay (%)					
		Storage duration (day)					
Number of pollination	Air speed (m/s)	0	15	30	45	60	Mean
Season 2018							
Control (manual pollination)		0.00	9.50	18.50	22.70	26.50	15.40
Mechanical one time	1.5	0.00	6.90	15.90	20.10	23.90	13.40
	1.6	0.00	6.10	15.10	19.30	23.10	12.70
	1.8	0.00	5.20	14.20	18.40	22.20	12.00
Mechanical two times	1.5	0.00	6.50	15.50	19.70	23.50	13.00
	1.6	0.00	5.30	14.30	18.50	22.30	12.10
	1.8	0.00	5.00	14.00	18.20	22.00	11.80
Mechanical three times	1.5	0.00	6.30	15.30	19.50	23.30	12.90
	1.6	0.00	5.10	14.10	18.30	22.10	11.90
	1.8	0.00	4.90	13.90	18.10	21.90	11.80
Mean		0.00	5.70	14.70	18.90	22.70	
LSD at 5%		A = 0.1		B = 0.1		A*B = 0.2	
Season 2019							
Control (manual pollination)		0.00	11.8	20.8	25.1	28.8	17.3
Mechanical one time	1.5	0.00	9.2	18.2	22.5	26.2	13.4
	1.6	0.00	8.40	17.40	21.70	25.40	12.70
	1.8	0.00	7.50	16.50	20.80	24.50	12.00
Mechanical two times	1.5	0.00	8.80	17.80	22.10	25.80	13.00
	1.6	0.00	7.60	16.60	20.90	24.60	12.10
	1.8	0.00	7.30	16.30	20.60	24.30	11.80
Mechanical three times	1.5	0.00	8.60	17.60	21.90	25.60	12.90
	1.6	0.00	7.40	16.40	20.70	24.40	11.90
	1.8	0.00	7.20	16.20	20.50	24.20	11.80
Mean		0.00	8.00	17.00	21.30	25.00	
LSD at 5%		A= 0.1		B = 0.1		A*B = 0.2	

Effect of Pollination-device Parameters and Cold-storage Duration on Fruit Decay-percent: Table (2) showed that decay percent significantly decreased by increasing air speed, number of pollination and significantly increased by increasing cold-storage duration.

The data indicated that maximum decay values of 23.9 and 26.2 % were obtained at first and second seasons of 2018 and 2019, respectively by using pollination machine one time at air speed of 1.5 m/s and cold-storage duration of 60 day. Meanwhile, the minimum decay values of 4.9 and 7.2 % were obtained at first and second seasons of 2018 and 2019, respectively by using pollination machine three times at air speed of 1.8 m/s and cold-storage duration of 15 day. The reduction of fruit loss by increasing cold-storage durations, air speed and number of pollination might be due to increasing of weight loss. The decreasing of decay percent by increasing air speed and number pollination was probably due to decreasing of fruit weight and size accordingly increasing of fruit firmness.

Effect of Pollination-Device Parameters and Cold-Storage Duration on Fruit Firmness: Table (3) showed that fruit firmness was significantly maintained by increasing air speed, number of pollination and significantly decreased by increasing cold-storage duration.

Moreover it could be found that the maximum fruit firmness values of 14.8 and 15.2 g/cm² were obtained at first and second seasons of 2018 and 2019, respectively by using pollination machine three times at air speed of 1.8 m/s and cold-storage duration of zero days. Meanwhile, the minimum fruit firmness values of 11.4 and 11.6 g/cm² were obtained at first and second seasons of 2018 and 2019, respectively by using pollination machine one time at air speed of 1.5 m/s and cold-storage duration of 60 day.

Fruit firmness was significantly decreased with the advancing of the storage period in both seasons. These results were partially in agreement with the results obtained by Zeinab *et al.* [22] on “Zaghloul” date-palm fruits.

Table 3: Effect of air speed and number of pollination on fruit firmness of “Zaghoul” date-palm fruits under cold storage during seasons of 2018 and 2019

		Firmness (g/cm ²)					
		Storage duration (day)					
Number of pollination	Air speed (m/s)	0	15	30	45	60	Mean
Season 2018							
Control (manual pollination)		12.40	12.20	12.00	11.90	11.10	11.90
Mechanical one time	1.5	12.80	12.60	12.30	12.10	11.40	12.20
	1.6	13.30	13.00	12.80	12.50	11.70	12.70
	1.8	13.80	13.50	13.20	13.00	12.20	13.10
Mechanical two times	1.5	13.20	12.90	12.70	12.50	11.70	12.60
	1.6	13.70	13.50	13.20	13.00	12.20	13.10
	1.8	14.30	14.10	13.80	13.60	12.80	13.70
Mechanical three times	1.5	13.60	13.40	13.10	13.00	12.10	13.00
	1.6	14.20	13.90	13.70	13.60	12.80	13.60
	1.8	14.80	14.50	14.30	14.10	13.30	14.20
Mean		13.60	13.40	13.10	12.90	12.10	
LSD at 5%		A= 0.01		B = 0.01		A*B = 0.02	
Season 2019							
Control (manual pollination)		12.5	12.30	11.90	11.60	10.80	11.80
Mechanical one time	1.50	13.10	12.90	12.60	12.40	11.60	12.50
	1.60	13.60	13.40	13.20	13.00	12.20	13.10
	1.80	14.10	13.80	13.50	13.30	12.50	13.40
Mechanical two times	1.50	13.50	13.30	13.00	12.80	12.00	12.90
	1.60	14.10	13.90	13.60	13.40	12.60	13.50
	1.80	14.60	14.40	14.10	13.90	13.10	14.00
Mechanical three times	1.50	14.00	13.80	13.50	13.30	12.50	13.40
	1.60	14.60	14.40	14.20	14.00	13.20	14.10
	1.80	15.20	14.90	14.60	14.40	13.60	14.50
Mean		14.10	13.90	13.60	13.40	12.60	
LSD at 5%		A= 0.01		B = 0.01		A*B = 0.02	

The increasing of fruit firmness by increasing air speed and number of pollination might be due to the reduction of fruit weight and size. The decreasing of fruit firmness by increasing cold-storage duration was probably due to rutab stage.

Effect of Pollination-Device Parameters and Cold-Storage Duration on Total Soluble Solids (TSS %): Table (5) showed that total soluble solids (TSS) significantly increased by increasing air speed, number of pollination and by increasing cold-storage duration from zero to 45 day and significantly decreased by increasing cold-storage duration from 45 to 60 day at two tested seasons.

Also, it was found that the maximum soluble solids (TSS) values of 12.4 and 12.7 % were obtained at first and second seasons of 2018 and 2019, respectively by using pollination machine three times at air speed of 1.8 m/s and cold-storage duration of 45 day. Meanwhile, the minimum fruit TSS values of 10.3 and 10.5 % were obtained at first and second seasons of 2018 and 2019, respectively by

using pollination machine one time at air speed of 1.5 m/s and cold-storage duration of 0 day.

The increasing of soluble solids (TSS) by increasing air speed and number of pollination might be due to decreasing of fruit weight and size. Meanwhile, the increasing of soluble solids (TSS) by increasing cold-storage duration from zero to 45 day was due to decreasing of fruit moisture-content.

Effect of Pollination-Device Parameters and Cold-Storage Duration on Acidity: The data presented in Table (5) indicated that acidity significantly increased by increasing air speed, number of pollination and by increasing cold-storage duration from zero to 50 day and significantly decreased by increasing cold-storage duration from 45 to 60 day at two tested seasons.

Moreover, results showed that the average acidity ranged between 0.37 - 0.76 and 0.37 – 0.98 % when cold-storage duration ranged between 0 – 45 and 45 – 60 day, respectively at the first season of 2018 and all tested air-speeds and numbers of pollination. Meanwhile, at the

Table 4: Effect of air speed and number of pollination on total soluble solids (TSS) content of “Zaghloul” date-palm fruits under cold storage during seasons of 2018 and 2019

		TSS (%)					
		Storage duration (day)					
Number of pollination	Air speed (m/s)	0	15	30	45	60	Mean
Season 2018							
Control (manual pollination)		10.20	10.60	10.90	11.10	10.30	10.60
Mechanical one time	1.50	10.30	10.60	11.00	11.30	11.20	10.90
	1.60	10.30	10.70	11.10	11.30	11.20	10.90
	1.80	10.70	11.00	11.40	11.70	11.50	11.30
Mechanical two times	1.50	10.30	10.70	11.10	11.40	11.30	11.00
	1.60	10.60	10.90	11.40	11.60	11.60	11.20
	1.80	11.00	11.30	11.80	12.00	11.90	11.60
Mechanical three times	1.50	11.00	11.40	11.90	12.10	12.10	11.70
	1.60	11.10	11.50	12.00	12.20	12.10	11.80
	1.80	11.30	11.70	12.20	12.40	12.30	12.00
Mean		10.70	11.00	11.50	11.70	11.60	
LSD at 5%		A=0.01		B=0.01		A*B=0.02	
Season 2019							
Control (manual pollination)		10.40	10.30	10.90	11.00	10.40	10.60
Mechanical one time	1.5	10.50	10.80	11.20	11.50	11.40	11.10
	1.6	10.60	10.90	11.30	11.50	11.50	11.20
	1.8	10.90	11.30	11.70	11.90	11.80	11.50
Mechanical two times	1.5	10.60	10.90	11.40	11.60	11.50	11.20
	1.6	10.80	11.10	11.60	11.90	11.80	11.40
	1.8	11.20	11.60	12.00	12.30	12.10	11.80
Mechanical three times	1.5	11.20	11.60	12.10	12.40	12.30	11.90
	1.6	11.30	11.70	12.20	12.50	12.30	12.00
	1.8	11.50	11.90	12.40	12.70	12.50	12.20
Mean		10.90	11.20	11.70	11.90	11.80	
LSD at 5%		A= 0.01		B=0.01		A*B=0.02	

Table 5: Effect of air speed and number of pollination on acidity percent of “Zaghloul” date-palm fruits under cold storage during seasons of 2018 and 2019.

		Acidity (%)					
		Storage duration (day)					
Number of pollination	Air speed (m/s)	0	15	30	45	60	Mean
Season 2018							
Control (manual pollination)		0.77	0.69	0.59	0.48	1.51	0.80
Mechanical one time	1.5	0.76	0.68	0.58	0.47	0.98	0.70
	1.6	0.74	0.66	0.56	0.46	0.96	0.70
	1.8	0.69	0.64	0.54	0.45	0.94	0.70
Mechanical two times	1.5	0.68	0.62	0.52	0.43	0.82	0.60
	1.6	0.67	0.61	0.51	0.41	0.79	0.60
	1.8	0.67	0.59	0.49	0.40	0.76	0.60
Mechanical three times	1.5	0.65	0.54	0.44	0.39	0.49	0.50
	1.6	0.63	0.53	0.43	0.39	0.47	0.50
	1.8	0.62	0.51	0.41	0.37	0.49	0.50
Mean		0.70	0.60	0.50	0.40	0.80	
LSD at 5%		A= 0.03		B = 0.02		A*B = 0.05	
Season 2019							
Control (manual pollination)		0.64	0.56	0.46	0.35	1.38	0.70
Mechanical one time	1.5	0.63	0.55	0.45	0.34	0.85	0.60
	1.6	0.61	0.53	0.43	0.33	0.83	0.50
	1.8	0.56	0.51	0.41	0.32	0.81	0.50
Mechanical two times	1.5	0.55	0.49	0.39	0.30	0.69	0.50
	1.6	0.54	0.48	0.38	0.28	0.66	0.50
	1.8	0.54	0.46	0.36	0.27	0.63	0.50
Mechanical three times	1.5	0.52	0.41	0.31	0.26	0.36	0.40
	1.6	0.50	0.40	0.30	0.26	0.34	0.40
	1.8	0.49	0.38	0.28	0.24	0.36	0.40
Mean		0.60	0.50	0.40	0.30	0.70	
LSD at 5%		A= 0.03		B = 0.02		A*B = 0.05	

Table 6: Effect of air speed and number of pollination on TSS/Acidity ratio of “Zaghloul” date-palm fruits under cold storage during seasons of 2018 and 2019

		TSS/Acidity (%)					
		Storage duration (day)					
Number of pollination	Air speed (m/s)	0	15	30	45	60	Mean
Season 2018							
Control (manual pollination)		13.25	15.36	18.47	23.13	6.82	15.40
Mechanical one time	1.5	13.55	15.59	18.97	24.04	11.43	16.70
	1.6	13.92	16.21	19.82	24.57	11.67	17.20
	1.8	15.51	17.19	21.11	26.00	12.23	18.40
Mechanical two times	1.5	15.15	17.26	21.35	26.51	13.78	18.80
	1.6	15.82	17.87	22.35	28.29	14.68	19.80
	1.8	16.42	19.15	24.08	30.00	15.66	21.10
Mechanical three times	1.5	16.92	21.11	27.05	31.03	24.69	24.20
	1.6	17.62	21.60	27.91	31.28	25.74	24.90
	1.8	18.23	22.94	29.76	33.51	25.10	25.90
Mean		15.60	18.40	23.10	27.80	16.20	
LSD at 5%		A= 0.04		B = 0.03		A*B = 0.07	
Season 2019							
Control (manual pollination)		16.25	18.39	23.60	31.43	7.54	19.50
Mechanical one time	1.5	16.67	19.64	24.89	33.82	13.41	21.70
	1.6	17.38	20.57	26.28	34.85	13.86	22.60
	1.8	19.46	22.16	28.54	37.19	14.57	24.40
Mechanical two times	1.5	19.27	22.24	29.23	38.67	16.67	25.20
	1.6	20.00	23.13	30.53	42.50	17.88	26.80
	1.8	20.74	25.22	33.33	45.56	19.21	28.80
Mechanical three times	1.5	21.54	28.29	39.03	47.69	34.17	34.10
	1.6	22.60	29.25	40.67	48.08	36.18	35.40
	1.8	23.47	31.32	44.29	52.92	34.72	37.30
Mean		19.70	24.00	32.00	41.30	20.80	
LSD at 5%		A= 0.04		B = 0.03		A*B = 0.07	

second season of 2019, the average acidity ranged between 0.24 - 0.63 and 0.24 – 1.38% when cold-storage durations ranged between 0 – 45 and 45 – 60 day, respectively at all tested air-speeds and numbers of pollination.

It was also found that the maximum acidity of 0.98 and 1.38 % were obtained at first and second seasons of 2018 and 2019, respectively by using pollination machine three times at air speed of 1.8 m/s and cold-storage duration of 60 day. Meanwhile, the minimum acidity values of 0.37 and 0.24 % were obtained at first and second seasons of 2018 and 2019, respectively by using pollination machine one time at air speed of 1.5 m/s and cold-storage duration of 0 day.

The increasing of acidity by increasing air speed and number of pollination might be due to the decreasing of fruit weight and size. The reduction of acidity by increasing cold-storage duration from zero to 50 day was probably due to increasing of TSS. The increasing of acidity by the advance of cold-storage durations from 45 to 60 day may be due to the decreasing of TSS.

Effect of Pollination-Device Parameters and Cold-Storage Duration on TSS/Acidity Ratio: Table (6) showed that the effect of air speed and number of pollination on TSS/Acidity ratio of “Zaghloul” date-palm fruits under cold storage during seasons of 2018 and 2019.

It was found that the maximum TSS/acidity of 33.51 and 52.92 % were obtained at first and second seasons of 2018 and 2019, respectively by using pollination machine three times at air speed of 1.8 m/s and cold-storage duration of 45 day. Meanwhile, the minimum TSS/acidity values of 11.43 and 13.41 % were obtained at first and second seasons of 2018 and 2019, respectively by using pollination machine one time at air speed of 1.5 m/s and cold-storage duration of 60 day.

Effect of Pollination-Device Parameters and Cold-Storage Duration on Fruit Tannins-Content: Table (7) showed that tannins content (mg/g) significantly decreased by increasing air speed, number of pollination and cold-storage duration at two tested seasons.

Table 7: Effect of air speed and number of pollination on tannins percent of “Zaghloul” date-palm fruits under cold storage during seasons of 2018 and 2019

		Tannins (mg/g)					
		Storage duration (day)					
Number of pollination	Air speed (m/s)	0	15	30	45	60	Mean
Season 2018							
Control(manual pollination)		3.58	3.16	2.85	1.75	1.49	2.60
Mechanical one time	1.5	3.53	3.12	2.81	1.70	1.44	2.50
	1.6	3.51	3.07	2.76	1.69	1.43	2.50
	1.8	3.49	3.06	2.75	1.68	1.42	2.50
Mechanical two times	1.5	3.47	3.01	2.7	1.66	1.4	2.40
	1.6	3.47	2.99	2.68	1.65	1.39	2.40
	1.8	3.43	2.97	2.66	1.62	1.36	2.40
Mechanical three times	1.5	3.43	2.95	2.64	1.60	1.34	2.40
	1.6	3.38	2.91	2.60	1.56	1.30	2.40
	1.8	3.32	2.86	2.55	1.51	1.25	2.30
Mean		3.50	3.00	2.70	1.60	1.40	
LSD at 5%		A= 0.03		B = 0.02		A*B = 0.05	
Season 2019							
Control (manual pollination)		3.36	3.06	2.60	1.68	1.40	2.40
Mechanical one time	1.5	3.31	3.01	2.56	1.63	1.35	2.40
	1.6	3.30	3.00	2.55	1.62	1.34	2.40
	1.8	3.29	2.99	2.50	1.61	1.33	2.30
Mechanical two times	1.5	3.27	2.97	2.49	1.59	1.31	2.30
	1.6	3.26	2.96	2.47	1.58	1.3	2.30
	1.8	3.23	2.93	2.45	1.55	1.27	2.30
Mechanical three times	1.5	3.21	2.91	2.43	1.53	1.25	2.30
	1.6	3.17	2.87	2.38	1.49	1.21	2.20
	1.8	3.12	2.82	2.32	1.44	1.16	2.20
Mean		3.30	3.00	2.50	1.60	1.30	
LSD at 5%		A= 0.03		B = 0.02		A*B = 0.05	

It was found that the maximum tannins of 3.53 and 3.31 % were obtained at first and second seasons of 2018 and 2019, respectively by using pollination machine one time at air speed of 1.5 m/s and cold-storage duration of zero days. Meanwhile, the minimum tannins values of 1.30 and 1.16 % were obtained at first and second seasons of 2018 and 2019, respectively by using pollination machine three times at air speed of 1.8 m/s and cold-storage duration of 60 day.

CONCLUSION

The best conditions which gave the suitable performance of pollination machine for “Zaghloul” date-palm were: three times of pollination operation, carried material of "flour + fine bran" with ratio of 1 : 1, air speed and 1.8 m/s. It gave a fruit set of 71.6 %, bunch-weight of 22.8 kg and fruit weight of 21.8 g. Moreover the average performance-rate of pollination machine was about 240 tree/ day. The best “Zaghloul” date-palm fruit-quality using the tested pollination-machine at previous best conditions at cold storage conditions of $0 \pm 1^{\circ}\text{C}$ with R. H.

85 – 90 % for best duration of 45 days were: weight loss of 4.7–5.2 %, decay of 20.5 – 20.6 %, fruit firmness of 14.1–14.4 mg/cm², TSS of 12.4 – 12.7 %, acidity of 0.24 – 0.37 %, TSS/Acidity ratio of 52.92 – 33.51 and tannins of 1.44 - 1.51 mg/g for seasons of 2018 and 2019.

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