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Impact of pollination time of the day on the fruit, yield, and quality traits of date palm cultivar Khalas

Muhammad Munir[1,2]*, Mohammed Refdan Alhajhoj[1], Abdel-Kader Mohammed Sallam[1,3], Hesham Sayed Ghazzawy[1,4] and Abdul Majeed Al-Bahigan[1]

*[1]Date Palm Research Center of Excellence, King Faisal University, Al-Ahsa, Saudi Arabia. [2]Frontier Agriculture, SOYL Precision Crop Production Division, Newbury, United Kingdom. [3]College of Technology and Development, Zagazig University, Egypt. [4]Central Laboratory for Date Palm Research and Development, Agriculture Research Center, Giza, Egypt. *E-mail: mmunir@kfu.edu.sa*

Abstract

The present study was conducted during the 2017 and 2018 seasons on date palm *cv.* Khalas to determine the most effective daytime to pollinate female palms to obtain optimum fruit-set, yield, and best fruit characteristics. Nine, twelve-year-old date palm trees were selected for the experiment, and five spathes from each palm were chosen for pollination. These palms were pollinated at three different daytimes, *i.e.*, at 8am (morning), 11am (late morning), and 2pm (afternoon). The experiment was laid out in Randomized Complete Block Design with three replicates for each treatment. The outcome of the study indicated significant differences among three pollination times. Date palm *cv.* Khalas, pollinated at 11am, exhibited significantly promising results regarding fruit-set percentage, parthenocarpic fruit percentage, biser fruit percentage, tamar fruit percentage, bunch weight, yield per palm, fruit fresh weight, fruit length, fruit width, fruit volume, pulp weight, pulp ratio, seed ratio, pulp:seed ratio, seed weight, seed length, and fruit moisture content; however, fruit drop percentage, seed width, total soluble solids, total sugar, reducing sugar, and non-reducing sugar were not significantly affected by any pollination time. Pollination carried out at 2pm closely following to 11am pollens application time, and a number of attributes were non-significant between the two times such as fruit-set percentage, parthenocarpic fruit percentage, biser fruit percentage, tamar fruit percentage, bunch weight, yield per palm, fruit volume and seed length. Early pollination time (8am) showed poor results regarding most of the attributes studied. Therefore, it is concluded that pollination should be carried out around the middle of the day when the ambient temperature is optimum, which favours pollen germination and positively influence fruit yield and quality attributes.

Key words: Date palm, *Phoenix dactylifera*, pollination times, fruit yield, and quality.

Introduction

Date palm (*Phoenix dactylifera* L.) is the main crop of oases, and one of the most distinctive features is its dioecious nature; the pollen-bearing male and fruit-bearing female flowers are borne on separate palms. Being a cross-pollinated species, it is anemophilous if left on natural pollination because male trees disseminate a large number of pollen grains, which carry away by the wind to pollinate and fertilise distant female palms (Tengberg, 2012). However, the overall yield is usually very low from open pollination, leading to the production of no economic value parthenocarpic fruits. It is not an effective method of pollination for long-distance pollinizers (Munir *et al*., 2020a) due to the high moisture content of the pollen grains that reduces fruit-set. Consequently, palm yield is decreased up to 50 percent. Therefore, artificial pollination is imperative and critical in the date palm production chain that improves fruit yield and quality and regulates annual tree bearing (Zaid and de Wet, 2002). This method of pollination is commonly practiced in commercial plantations, which is based on various techniques such as hand or manual pollination, male pollen strands (spikelets) are placed onto female spathe (inflorescence); dusting pollination, pollen grains powder is dusted onto female spathe with the help of cotton balls or dusting machines; and liquid pollination, pollen grains suspension is sprayed onto female spathe with the help of handheld sprayer or a mechanised spraying machine (Zaid and de Wet, 2002; Hajian, 2005; Munir, 2019; Munir *et al*., 2020c).

Artificial pollination is carried out after cracking of the female spathe, which, if delayed, affects stigma receptivity and decreases the yield by up to 70 percent (Marzouk *et al*., 2002; Munir *et al*., 2020b). The time of stigma receptivity varied from cultivar to cultivar, from twenty-four hours (Nasir *et al*., 1994) to more than twenty days (Rahim, 1975). The same cultivars can show different duration of receptivity in different years, such as *cvs.* Sabbaka and Roushodia set the highest number of fruits when pollinated after the fourth day of spathe cracking in the first year of study. In contrast, the stigma of the same cultivars was more receptive for only two days in the next year (Attalla *et al*., 1998). Ream and Furr (1969) stated that the stigma of date palm has a limited time of pollen receptivity, three to four days in some cultivars. Rahim (1975) reported that pollination practice could be done within five days after female spathe opening in *cv.* Zaidi, however, can be delayed up to twenty days in *cvs.* Barban and Khudrawi. The best pollination time was observed as four days after the spathe opening in *cv.* Khalas (Dowson, 1982); however, Hussain *et al*. (1984) suggested two to four days of pollination for the same cultivar. Iqbal *et al*. (2004) suggested that *cv.* Dhakki should be pollinated within four days after spathe cracking. On the other hand, they observed that pollination done on the first day of spathe splitting set more fruits and enhanced yield in *cv.* Gulistan, however, the delayed pollination time improved the fruit quality but decreased yield and increased fruit drop (Iqbal *et al*., 2017).

After pollen visited the stigma of an ovary, the initiation of the pollen tube is precisely guided by female cues (Higashiyama and Takeuchi, 2015), and several female-secreted peptides are identified that precisely control the direction of pollen tube growth (Okuda *et al*., 2009; Takeuchi and Higashiyama, 2012). Previous studies on date palm pollination were mainly focused on the duration of stigma receptivity; however, it also depends on the environmental factors (Zaid and de Wet, 2002). Once pollen grains are discharged from anthers, they become independent functional units and are subjected to the ambient environment. Consequently, they are more severely affected by environmental factors than the ovules (Kakani *et al*., 2005). The germination of pollen grains in response to temperature is reported in many crops; however, the optimum temperature for pollen germination varies with the species (Pérez *et al*., 2019; Çetinbaş-Genç *et al*., 2019) and even between the cultivars of the same species (Acar and Kakani, 2010). In date palm *cv.* Dhakki, pollination carried out at the warmer time of the day (at noon) was most effective regarding fruit-setting, yield, and fruit size parameters (Iqbal *et al*., 2014).

In hot arid regions, date palm is pollinated in March-April, depending on the cultivars' floral response. Date palm *cv.* Khalas is grown extensively in the Eastern province of Saudi Arabia, and its female inflorescence emergence occurs in March. The date palm growers in this region usually do pollination in the morning time when the temperature is mild, which later on ascends to warm at noon and afternoon. Due to this practice, the fruit-set is minimised that eventually decreases the overall yield. Moreover, the issues of parthenocarpic and biser fruits production predominate. Therefore, the present study was carried out to reveal the most appropriate time of the day for the pollination of date palm *cv.* Khalas and its effect on fruit, yield, and physicochemical characteristics under the climatic condition of Al-Ahsa, Saudi Arabia.

Materials and methods

The study was conducted at the Research and Training Station, King Faisal University, Al-Ahsa, Kingdom of Saudi Arabia (Latitude 25° 16' 7.068'' N and Longitude 49° 42' 27.522'' E) during the 2017 and 2018 seasons. Twelve-year-old matured male spathes (inflorescence) were collected from the experimental orchard to obtain pollen grains for pollination purposes. The protective sheath of male spathes was removed with the help of a sharp bird's beak knife and were placed on Kraft brown paper sheet at ambient room temperature for 24 hours. Pollen grains were collected by shaking the strands of the spathes, dried in a glass desiccator, and kept in a refrigerator at 4ºC. The pollen grains powder was mixed with plain flour (1:9) and dusted onto female spathe with soft cotton balls (Johnson and Johnson, UAE) at three-time internals of the day, *i.e.*, at 8am (morning), 11am (late morning) and 2pm (afternoon). Nine uniform female date palm *cv.* Khalas trees of twelve-year age were chosen for the experiment, in which five spathes on each palm were selected, and the rest were removed. The experiment was laid out on Randomized Complete Block Design with three replicates in each treatment. All female pollinated spathes were covered with the Kraft brown wax paper bags to avoid contamination, which were removed after fruit-setting (15 days after pollination). Around mid-summer, each fruit bunch was covered with knitted polyethylene mesh bags (90 × 80 cm) for protection from birds and insects. The agro-climatic data downloaded from the on-farm wireless weather station, Model WS3083 (Aercus Instruments, West Yorkshire, UK), installed around 25 meters away from the experimental orchard (Table 1). All the standard cultural practices were carried out uniformly. The data were recorded on the following variables: Fruit-set percentage, parthenocarpic fruit percentage, biser fruit percentage, tamar fruit percentage, fruit drop percentage, bunch weight, yield per palm, pulp weight, pulp ratio, seed ratio, and pulp:seed ratio, fruit fresh weight, fruit length, fruit width, fruit volume, seed weight, seed length, seed width, fruit moisture content, total soluble solids, total sugar, reducing sugar and non-reducing sugar according to AOAC standard methods (AOAC, 2016). The collected data were statistically analysed according to Gomez and Gomez (1984), using Statistical Analysis Software, Release 9.4 (SAS Institute, North Carolina, USA), and the Duncan Multiple Range Test was applied to determine the least significance difference between the means (Waller and Duncan, 1969).

Results

Data given in Table 2 showed a statistically significant ($P \leq 0.05$) effect of different pollination timings on the fruit-set percentage, parthenocarpic (unfertilized or *Shees*) fruit percentage, biser (unripe) fruit percentage, tamar (ripe) fruit percentage, bunch weight, and yield per palm of date palm *cv.* Khalas. However, there was a non-significant effect of different pollination timings

Table 1. Climatic information of the research site during experimental years 2017-18

Growing Season	2017-18 Temperature (°C)			Relative humidity (%)		Wind speed (km/h)		Precipitation (mm)	
	Max.	Min.	Average						
	2017-18	2017-18	2017-18	2017	2018	2017	2018	2017	2018
March	28-34	16-17	22-25	18 > 70	6 > 51	2 > 45	3 > 41	0.00	0.00
April	38-35	21-21	29-28	6 > 43	9 > 55	4 > 50	4 > 56	0.00	2.15
May	43-40	26-24	35-32	5 > 31	5 > 38	3 > 54	3 > 45	0.00	0.84
June	45-45	28-30	36-38	4 > 21	4 > 23	5 > 56	6 > 58	0.00	0.00
July	48-46	30-31	39-39	4 > 31	4 > 25	2 > 39	5 > 62	0.00	0.00
August	46-46	30-29	38-38	6 > 51	4 > 29	1 > 33	5 > 53	0.00	0.00
September	44-44	26-27	35-35	6 > 61	6 > 61	1 > 41	1 > 33	0.00	0.00

Maximum, minimum, and average temperature in each cell represent the year 2017 and 2018 values. Relative humidity and wind speed in each year represent the minimum to maximum average values.

on the fruit drop percentage. Maximum fruit-set (81.63% and 81.59%) was recorded when pollens were applied at 11am and 2pm, respectively, as both were statistically at par; however, it was minimum (71.45%) when female flowers were pollinated at 8am. Data regarding parthenocarpic fruit percentage indicated that the female bunches pollinated at 2pm (2.46%) and 11am (2.58%) had a minimum percentage of parthenocarpic fruits. In contrast, bunches pollinated at 8am produced significantly higher parthenocarpic fruits (10.61%). A similar trend was observed regarding biser fruit percentage, as the lowest percentage (2.29%) was noted in 11am application time, which was statistically alike to 2pm application time (3.81%); however, the highest biser percentage (6.80%) was recorded at 8am pollinated time. Data regarding tamar fruit percentage indicated the highest percentage (79.34%) when female spathes were pollinated at 11am followed by 2pm application time (77.77%), which was statistically non-significant to the former one; however, it was minimum (64.64%) when *cv.* Khalas was pollinated at 8am. Although the fruit drop percentage was non-significant statistically, it was minimum when female bunches were dusted at 11am (15.79%), which was at par with 2 pm application time (15.95%). In contrast, maximum fruit drop (17.94%) was observed in the 8am treatment. The trend observed for bunch weight showed a maximum (6.46 kg) when pollens were dusted at 11am and statistically alike with 2pm application time (6.23 kg). A significantly reduced bunch weight (3.01 kg) was observed when female palms were pollinated at 8am. A similar response was noted regarding yield per palm data, *i.e.*, the highest yield per palm (32.31 kg and 31.15 kg) was obtained when palms were pollinated at 11am and 2pm, respectively. In contrast, it was a minimum (15.03 kg) at early pollination time (8am).

Table 3 indicated that the effect of different pollination times of the day was statistically significant ($P \leq 0.05$) regarding fruit fresh weight, fruit length, fruit width, fruit volume, pulp weight, pulp ratio, seed ratio, pulp:seed ratio, seed weight, seed length and fruit moisture content of date palm *cv.* Khalas. However, there was non-significant effect of pollination times on seed width, total soluble solids, total sugar, reducing sugar, and non-reducing sugar. Maximum fruit fresh weight (11.20 g), fruit length (36.38 mm), fruit width (23.56 mm), and fruit volume (10.99 mL) were measured when the female bunches were pollinated at 11am, which was followed by 2pm pollens application time, fruit fresh weight (9.81 g), fruit length (35.05 mm), fruit width (21.21 mm) and fruit volume (10.33 mL). On the other hand, these parameters were minimum when pollination was carried out at 8am, *i.e.*, fruit fresh weight (8.11 g), fruit length (32.09 mm), fruit width (21.09 mm), and fruit volume (8.99 ml). Data regarding pulp weight showed that it was maximum (10.27 g) when pollens were applied at 11am followed by 2pm application time (8.75 g); however, the same parameter was recorded minimum (7.02 g) at 8am application time. Similarly, female spathes pollinated at 11am had a higher pulp ratio (91.67) followed by 2pm application time (89.15) and decreased to 86.46 at the 8am time of application. The seed ratio trend was opposite to the pulp ratio wherein maximum seed ratio (13.54) was recorded when pollination was done at 8am followed by 2pm (10.85), and 11am (8.33) application times. Maximum pulp:seed ratio (11.31) was observed when pollen dusting was done at 11am; however, it was minimum (6.48) at 8am pollination time followed by 2pm (8.25) time, and both were statistically at par. Data regarding seed weight was higher (1.09 g) when the pollination was carried out at 8am followed by 2pm application time (1.06 g), whereas it was minimum (0.93 g) at 11am pollination time. A more or less similar trend was observed regarding the seed length variable, where it was maximum at 8am application time (22.16 mm) and minimum at 11am (19.12 mm) followed by 2pm pollination time (20.04 mm). Although the seed width was non-significant statistically, however, it was linearly decreased from 8am (7.90 mm), 11am (7.72 mm), and 2pm (7.42 mm) application times. Chemical analysis of the tamar fruits of date palm *cv.* Khalas revealed that apart from fruit moisture content, all other parameters (total soluble solids, total sugar, reducing sugar, and non-reducing sugar) were non-significant statistically. Maximum fruit moisture content (17.91%)

Table 2. Effect of different pollination timing on the fruit-set percentage, parthenocarpic fruits percentage, biser fruits percentage, tamar fruits percentage, fruit drop percentage, bunch weight, and yield per palm of date palm *cv.* Khalas.

Parameters	Pollination Timing			$LSD_{(5\%)}$
	8am	11am	2pm	
Fruit-set (%)	71.45^b (±2.20)	81.63^a (±1.87)	81.59^a (±1.60)	7.20*
Parthenocarpic fruits (%)	10.61^a (±0.50)	2.58^b (±0.31)	2.46^b (±0.54)	0.99*
Biser fruits (%)	6.80^a (±1.13)	2.29^b (±0.60)	3.81^b (±0.64)	2.66*
Tamar fruits (%)	64.64^b (±2.61)	79.34^a (±1.97)	77.77^a (±1.86)	7.97*
Fruit drop (%)	17.94^a (±1.80)	15.79^a (±2.07)	15.95^a (±1.66)	7.21^{NS}
Bunch weight (kg)	3.01^b (±0.25)	6.46^a (±0.38)	6.23^a (±0.20)	0.95*
Yield per palm (kg)	15.03^b (±1.26)	32.31^a (±1.90)	31.15^a (±1.00)	4.75*

Similar letters in a row are non-significant at 5% level of probability. Figures in parentheses represent the variability within replicates. NS indicates the non-significant statistical difference between the means of each treatment, whereas * represents the significant statistical difference.

Table 3. Effects of different pollination timings on the physicochemical characteristics of fruit of date palm *cv.* Khalas

Parameters	Pollination timing			$LSD_{(5\%)}$
	8am	11am	2pm	
Fruit fresh weight (g)	8.11^c (±0.44)	11.20^a (±0.37)	9.81^b (±0.20)	1.06*
Fruit length (mm)	32.09^{ab} (±1.39)	36.38^a (±1.16)	35.05^b (±1.07)	3.34*
Fruit width (mm)	21.09^b (±0.54)	23.56^a (±0.63)	21.21^b (±0.53)	1.94*
Fruit volume (ml)	8.99^b (±0.40)	10.99^a (±0.33)	10.33^a (±0.47)	1.13*
Pulp weight (g)	7.02^c (±0.43)	10.27^a (±0.37)	8.75^b (±0.21)	1.07*
Pulp ratio	86.46^b (±0.72)	91.67^a (±0.63)	89.15^c (±0.32)	2.06*
Seed ratio	13.54^b (±0.72)	8.33^c (±0.63)	10.85^a (±0.32)	2.06*
Pulp:Seed ratio	6.48^b (±0.43)	11.31^a (±1.01)	8.25^b (±0.29)	2.24*
Seed weight (g)	1.09^a (±0.03)	0.93^b (±0.07)	1.06^{ab} (±0.01)	0.15*
Seed length (mm)	22.16^a (±0.25)	19.12^b (±0.34)	20.04^b (±0.29)	0.94*
Seed width (mm)	7.90^a (±0.24)	7.72^a (±0.31)	7.42^a (±0.33)	0.41^{NS}
Fruit moisture content (%)	17.91^a (±0.62)	15.23^b (±0.54)	15.64^{ab} (±0.68)	2.42*
Total soluble solids (Brix)	64.93^a (±1.92)	65.68^a (±1.56)	65.64^a (±1.28)	4.62^{NS}
Total sugar (%)	56.21^a (±0.47)	57.28^a (±0.47)	56.30^a (±0.79)	2.05^{NS}
Reducing sugar (%)	54.06^a (±0.48)	55.12^a (±0.48)	54.00^a (±0.90)	2.46^{NS}
Non-reducing sugar (%)	2.16^a (±0.26)	2.16^a (±0.29)	2.31^a (±0.13)	0.81^{NS}

Similar letters in a row are non-significant at 5% level of probability. Figures in parentheses represent the variability within replicates. NS indicates the non-significant statistical difference between the means of each treatment, whereas * represents the significant statistical difference.

was determined when the female bunches were pollinated at 8am followed by 2pm pollination time (15.64%), whereas it was minimum (15.23%) when pollens were applied at 11am. Among non-significant variables, pollination practiced at 11am gave maximum total soluble solids (65.68 Brix), total sugar (57.28%), and reducing sugar (55.12%), whereas non-reducing sugar was slightly higher (2.31%) when pollination was carried out at 2pm.

Discussion

Most of the available research literature on date palm pollination times of the day focused on the pollination frequencies after the anthesis of female inflorescence. The anthesis of a flower is the period during which a flower is fully opened and functional. Many studies conducted on this aspect indicated how long a female flower remains receptive to respond to the male pollen grain for fertilization (Nasir *et al*., 1994; Attalla *et al*., 1998; Hussain *et al*., 1984; Iqbal *et al*., 2004, 2017). The results of the present study indicated that pollination carried out at 11am and 2pm (when the initial day temperature was high and RH was low) significantly enhanced fruit-set percentage, tamar fruit percentage, bunch weight, yield per palm, fruit weight, and size, pulp ratio, and pulp:seed ratio. Similar results were reported by Iqbal *et al*. (2014) in date palm *cv.* Dhakki when the pollination practice was carried out at 12 pm (noon) regarding fruit-set, fruit weight and size, and tree yield. Similarly, Daud and Ahmed (2008) also observed a high fruit-set when pollination performed at 12pm. Attalla *et al*. (1998) also observed that the fruit length of Saudi date palm cultivars varied with the pollination day timing. However, Albajallani *et al*. (1989) stated that pollination timing (morning-noon-afternoon) had no significant effect on fruit-set in *cv.* Sukhari. Although the present study indicated a significant impact of pollination timings on parthenocarpic, biser, and tamar fruits, however, there are many other reasons for parthenocarpic fruit development such as male or female incompatibility (Zaid and de Wet, 2002), environmental factors (Pandolfini *et al*., 2018), hormonal deregulation (Jacobsen and Olszewski, 1993), delay or rapid growth of ovary due to the changes in the regulation of gibberellin (Smith and Koltunow, 1999) and low temperatures (Cohen *et al*., 2016). In the present study, female bunches pollinated early in the morning (8am) when the initial temperature was low produced minimum fruit-set (71.45%) and maximum parthenocarpic fruits (10.61%) that could be due to the failure of pollen tube growth to fertilize female ovary. The unripe biser fruits are produced by the biochemical changes, low respiration rate, low external temperature, and inappropriate relative humidity during fruit development phases. Due to the climacteric nature of the fruit, the ripening processes are associated with a concurrent increase in the internal ethylene concentration and a higher rate of respiration (Abbas and Ibrahim, 1996, 1998). They are used as benchmarks in establishing fruit ripening. However, a few reports described the absence or reduced peak in respiration when fruits are ripened on the tree, despite a distinct rise in ethylene concentration (Saltveit, 1993; Bower *et al*., 2002). Therefore, any change in these factors adversely affects the fruit ripening process.

It can be concluded from the findings of the present study that female spathes pollinated at 11am (late morning) significantly improved the fruit-set percentage, bunch weight, yield per palm, and physical fruit properties. However, pollination at 2pm (afternoon) was also closely followed in certain variables. The chemical fruit properties of *cv.* Khalas were not influenced by the time of pollination. The late morning (11am) and afternoon (2pm) pollination times were the best due to the high initial temperature and low RH that might accelerate pollen tube growth. Early application of pollen grains (8pm) showed poor results due to the low initial temperature and high RH, which might slow down the pollen tube growth. However, further *in-vitro* and *in-vivo* studies can be conducted to pinpoint the precise temperature and RH, favouring pollen tube growth using respective environmental sensors and dataloggers.

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