

Review Article

Artificial Pollination: A Tool for Improving Fruiting Traits in Date palm (*Phoenix dactylifera* L.)

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Abstract

The term ‘artificial pollination’ refers to the aid in pollination by human with a desired pollen source, so as to improvise various fruiting traits in a dioecious fruit crop like date palm. Owing to the mysterious significance of metaxenia, there is a scope of improvisation of the yield and quality traits of dates. The selection of the pollen source greatly determines the desired success in the artificial pollination programmes. In case of artificial pollination in date palm, some pollen parents contribute towards the increase in yield, whereas some improve the fruit quality or hasten the physiological maturity period. In present unpredictable and highly fluctuating climatic context, the alteration in the time of fruit maturity can be of great use.

Keywords: Pollination, Fruit, Quality, Metaxenia, Phoenix

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Introduction

Date palm, *Phoenix dactylifera* L., is a perennial long-lived dioecious monocotyledon of great socio-economic importance [1]. These ‘trees’ are cultivated not only for their valuable fruits (dates), but also for producing fuel, fibre and as shelter for ground crops. It also provides a favourable environment for the cultivation of other species such as olives, figs, vegetables and so on [2]. Production of dates is of approximately 6.8 million metric tons around the world and generates an important commercial activity [3]. Countries such as Egypt, Islamic Republic of Iran and Saudi Arabia represent the top three producers worldwide. It is also found in Canary Island, Northern Africa, the Middle East, Pakistan, India and the U.S. state of California. Date palms fulfil various roles, from food and religion to construction and ornamentation. It is used on both fresh and dry forms. It is one of the most delicious and nutritious fruit containing high calorific value and sugars [4]. In these different ways, palm trees contribute to the food, housing, furniture, energy, clothing and gardens [5].

Failure of effective pollination leads to the formation of triple parthenocarpic fruits of no economic value [6]. Although fertilization and fruit set are the two major results of pollination, there is still another interesting but uncommon effect called ‘Metaxenia’: the direct influence of pollen on the maternal tissues of the fruit [7]. It has been observed that some date cultivars had better yield when pollinated with selected males rather than with other [8]. To make pollination effective, it is better if 2 to 3 strands of male flowers are inserted between strands of female spathe. To meet with this problem of artificial pollination is considered to be the most important factor affecting fruit set and yield [9]. Floral spike branches arise from the axils of the leaves that emerged previous year. This process relies essentially on wind. However, to guarantee high productivity, artificial pollination is commonly practiced in commercial plantations. This consists of placing a portion of a male flower spike on the female inflorescence.

Pollen source has been reported to effect fruit set, ripening and quality [10]. The direct influence of pollen on the maternal tissues of the fruits was recorded in many cultivars of date palms [11-13]. Most of the male palms available are of seedling origin with great variations in their pollen quality. Pollen can change some fruit morphological properties and fruit texture which effect on the endosperm (embryo and albumen). It affects fruit size, shape, weight and time of ripening. These effects on tissue of purely maternal origin, rather than on parts resulting from syngamy have been described as ‘Metaxenia’ [12, 14-16]. Owing to the xenia and metaxenia, a wide variation is observed in terms of morphological as well as various biochemical attributes in case of date palm fruit. It directly influences the fruit size, fruit development rate and most importantly, the time of fruit ripening [9, 12]. The time of fruit ripening is important for date palm, particularly in North India, because when the ripening time coincides with rainy days, a huge loss in yield and fruit quality is observed. Hence, selection of pollen parent carries immense significance in date, in which artificial pollination is commercially practised. Pollens from other related species of date palm like *Phoenix reobelenii*, *P. reclinata*, *P. canariensis* and *P. rupicola* were also successfully used to produce date fruits [11].

Recently, the pollens of *Phoenix pusilla* (dwarf date palm) male were successfully used to pollinate female date palm cultivars [17].

Given the harsh conditions in the habitat of date palm trees, the crop faces many challenges with respect to soil, salinity, heat and water scarcity. Also, the plant is often grown in large plantations that require very little maintenance and inputs. Therefore, such an important botanical, ecological and economical species deserves a breeding program in accordance with the needs of its market growth and development and of its productivity and date quality. The history of the genetic improvement of these species and the main scientific and technological developments eyeing to improve the various fruiting traits has been presented here. In this review the effect of different pollinizers on various cultivars of date palm to improve fruit yield as well as quality has been illustrated.

Physical Parameters

Fruit set percentage

Abdel-Hamid [18] studied six males as different pollen sources for Zaghoul date palm, revealed that Maghal-1, Zaghoul and Hayany males showed highly metaxinic effect and gave highest fruit set as compared to other male parents. Al-Khalifah [19] also evaluated the effect of five pollen samples of date palm (*Phoenix dactylifera* L.) on the maternal tissues of fruits in two cultivars, namely 'Barhy' and 'Nabtet-Saif'. Significant variation in percentage of abnormal fruit setting was observed. In the female cultivar 'Barhy', the 'Kacst' pollen reduced the formation of abnormal fruits to a significantly lower level while in 'Nabtet-Saif' the 'Fouzan' pollen controlled the abnormal fruit setting to a certain level. Al-Hamoudi *et al.* [20] evaluated the some male types as pollinator for Barhi date palm cv. and studied the effect of these pollinators on fruit set and quality of Barhi date palm. He observed that Ghanamy pollens recorded the highest significant fruit set percentages (34.15% and 33.03%). Iqbal *et al.* [21] observed the maximum fruit set of 92.33 per cent, when Zahidi was pollinated with male M2 while, the same pollens resulted in minimum fruit set in Dhakki. However, El-Hamady *et al.* [22] observed that date palm cv. 'Hayany' showed higher fruit set (26.02%), when pollinated with male M2. Whereas, Sudhersan *et al.* [16] reported the xenic and metaxenic effect of *Phoenix pusilla* pollen on certain date palm cultivars and noticed similar to the normal date palm pollination. Similarly, Iqbal *et al.* [23] studied the effect of different *dactylifera* males (M1-M9) and their whorl pollen grains on fruit set, fruit drop and fruit characteristics of 'Dhakki' date palm in 2007 and 2008. He observed that pollinated trees gave economical fruit set (93.55%) with M2 male during 2007 and with M1 male during 2008 (81.11%). The effects of pollinator type and pollination method on fruit set and fruit characteristics of 'Nabbut-Ali' and 'Sabbaka' date palm cultivars which are suffering partial fruit set failure. He observed that in both cvs. the pollinator 'Hada-9' gave the highest fruit set (36.0% and 23.3%) for Nabbut-Ali' and 'Sabbaka respectively [24].

The effect of different *dactylifera* male pollinizer on the pomological traits of Shakri, Zahidi and Dhakki date palm was reported by Iqbal *et al.* [25] and they found that the highest fruit set percentage of 96.72 per cent and 96.50 per cent was recorded when M4 pollens were used. The M10 pollen produces the highest fruit set at both kimri and rutab stage out of twelve pollen sources in cv. Barhi [26]. Mustafa *et al.* [27] studied the effect of pollinizer sources on yield and fruit characteristics of 'Ahmat' cv. date palm (*Phoenix dactylifera* L.). They observed that Noubaria pollen grain gave the highest fruit set. Metaxenic effects of *Phoenix dactylifera* and *Phoenix canariensis* on yield and quality of Khalas fruit and found that bunches pollinated by pollen from *Phoenix dactylifera* significantly increased fruit set percentage [28]. They also reported the effect of pollen sources on yield and fruit quality of 'Khalas' date palm and they observed that male M1 gave the maximum fruit set (57.82%).

The effect of two pollinizers (Meghal 1 and Meghal 2) on fruit characteristics of 'Zaghoul' date palm cv. showed that the fruit set percentage improved by 28.30 per cent when using pollens of Meghal 1 [29]. The effect of three different date palm male types namely Abo Rawash, Rashid and El Nubaria on yield and fruit quality of 'Samany' date palm cv. The Abo Rawash pollens significantly improve the fruit set percentage [30]. Similarly, Omaira *et al.* [31] studied the effect of three pollen grain sources namely Giza, Aswan and El-wady El-Gadid on yield and fruit quality of Samany Date Palm cv. (*Phoenix dactylifera* L.). The pollination with "Giza" pollen grains exhibited the highest fruit set percentage (82.67 and 83.0%). In Siwi date palm Sarrwy *et al.* [32] found the the highest fruit set percentage with Rashid and Noubaria pollen grains.

Fruit length

Al-Hamoudi *et al.* [20] evaluated the some male types as pollinator for Barhi date palm cv. and studies the effect of these pollinators on fruit set and quality of Barhi date palm. Fard pollen produced the highest value for fruit length

(2.64 cm). The effect of male pollinizers on fruit characteristics and yield index of 'Zahidi' and 'Dhakki' date palm cultivars showed the maximum fruit length of 4.70 cm when cv. Dhakki was pollinated with male M3 and minimum fruit length of 2.27 cm when cv. Zahidi was pollinated with M3 [21]. In date palm cv. 'Hayany' the pollination with M2 gave higher fruit length than M1 pollens [22]. Sudharsan *et al.* [16] studied the xenic and metaxenic effect of *Phoenix pusilla* pollens on certain date palm cultivars and observed that the size of fruit in 'Barhi' was a little smaller than the fruit size attained by normal date palm pollen, while in the other two cultivars, 'Madhool' and 'Sultana', fruits were almost equal to the size of the normal fruit. The effect of three pollinizers (NP3, NP4 and a local male) on yield and fruit quality of 'Najda' date palm cv. (*Phoenix dactylifera* L.) revealed that pollination by 'NP3' or 'NP4' significantly improved fruit length by 1 cm [33].

Iqbal *et al.* [23, 25] studied the effect of different *dactylifera* males (M1-M9) and their whorl pollen grains on fruit set, fruit drop and fruit characteristics of 'Dhakki' date palm in 2007 and 2008. It was observed that the M1 pollen produced longer fruit (4.88 cm) in 2007, while pollination with M8 excelled in fruit length (5.26 cm) in 2008. Farag *et al.* [34] investigated the metaxenic effect of two date palm male pollinizers on physical and chemical properties of cv. Zaghoul. The results proved that pollinizer A (Balteem 14) caused significant increase in fruit size. The significantly maximum average fruit length (3.68 cm and 3.73 cm) was observed in fruits of date palm cvs. Shakri, Zahidi and Dhakki fertilized with pollinizer M1 during the years 2005 and 2006 [25]. Studies on influence of twelve pollen sources on fruit production of date palm cv. Barhi concluded that the Fard no. 4 pollen grains gave the highest fruit length [26]. The effect of pollinizer sources on yield and fruit characteristics of 'Ahmat' cv. date palm (*Phoenix dactylifera* L.) showed Ahmat date pollinated by Noubaria pollen grain gave the highest fruit length [27]. Omar *et al.* [35] reported the effect of pollen sources on yield and fruit quality of 'Khalas' date palm and observed that the trees pollinated with male M1 pollens cause significant increase in fruit length. Rashid pollinizer gave the highest fruit length in cv. Siwi [32]. The pollination with "Giza" pollen grains gave the highest fruit length in Samany date palm [31].

Fruit breadth

Iqbal *et al.* [21] studied the effect of male pollinizers on fruit characteristics and yield index of 'Zahidi' and 'Dhakki' date palm cultivars. He observed the maximum fruit breadth of 2.6cm in Dhakki when male M1 pollens were used while minimum fruit breadth of 1.70 cm was observed when Zahidi was pollinated with male M3 pollens. Pollination by 'NP3' or 'NP4' significantly improved fruit width by 3mm in Najda date palm [33]. Pollination with M1 male palm significantly increased the mean breadth (2.31 cm and 2.37 cm) in date palm cvs. Shakri, Zahidi and Dhakki during 2005 and 2006 [25].

Fruit weight

Helail and El-Kholey [36] noted the increase in fruit weight of Khadrawi date palm cv. when pollinated by Rasheid pollens. Increased in fruit weight was observed in Malkabi cv. of date palm with Kom-Ambo pollen grains [37]. Al-Khalifah [19] evaluated the effect of five pollen samples of date palm (*Phoenix dactylifera* L.) on the maternal tissues of fruits in two cultivars, namely 'Barhy' and 'Nabtet-Saif'. Both 'Barhy' and 'Nabtet-Saif' produced smaller fruits with 'Heet' pollens while 'Fouzan' and 'Muzahmiya' pollen grains resulted in the production of bigger fruits in 'Barhy'. In 'Nabtet-Saif' better results were obtained with 'Dilim' pollen. Al-Hamoudi *et al.* [20] evaluated the some male types as pollinator for Barhi date palm cv. and studies the effect of these pollinators on fruit set and quality of Barhi date palm. Fard pollen produced the highest values for fruit weight (16.08 and 17.00 g). The effect of male pollinizers on fruit characteristics and yield index of 'Zahidi' and 'Dhakki' date palm cultivars showed that the maximum fruit weight was obtained when both the cvs. Dhakki and Zahidi were pollinated with male M3 [21] and in cv. Hayany with pollinizers M1 [22]. Similarly, Zirari [33] studied the effect of three pollinizers (NP3, NP4 and a local male) on yield and fruit quality of 'Najda' date palm cv. (*Phoenix dactylifera* L.). He found that pollination by 'NP3' or 'NP4' significantly improved fruit weight by 35 per cent as compare to the control. Iqbal *et al.* [23] studied the effect of different *dactylifera* males (M1-M9) and their whorl pollen grains on fruit set of 'Dhakki' date palm in 2007 and 2008. They observed that the highest fruit weight of 18.14 g was recorded when trees were pollinated with M9 in 2007 and with M5 in 2008 (15.18 g). Farag *et al.* [34] investigated the metaxenic effect of two date palm male pollinizers on physical and chemical properties of cv. Zaghoul. The results proved that pollinizer A (Balteem 14) caused significant increase in fruit weight. The significantly maximum fruit weight of 11.64 g and 11.60 g was recorded in fruits produced by pollination of M1 pollens in date palm cvs. Shakri, Zahidi and Dhakki [25] and [28] in Khalas date palm. The influence of twelve pollen sources on fruit production of date palm cv. Barhi and he concluded

that the highest fruit weight (16 g) was obtained with Fard no. 4 and lowest (12.85g) with M12 pollens [26]. The effect of different pollen sources (male A, B and C) on physical and chemical properties of four female cvs. showed that male B gave the highest fruit weight as compare to male A and male C [38]. Mustafa *et al.* [27] reported the effect of pollinizer sources on yield and fruit characteristics of 'Ahmat' cv. of date palm (*Phoenix dactylifera* L.). It was observed that Ahmat date pollinated by Noubaria pollen grain gave the highest fruit weight in first season whereas in second season Rashid pollinizers gave the highest fruit weight. The effect of pollinizers (Meghal 1 and Meghal 2) on fruit characteristics of 'Zaghloul' date palm cv. showed that the maximum fruit weight (25.70 g) was recorded when Meghal 2 pollens were used [29]. Omaima *et al.* [30] studied the effect of pollens of three different date palm male types namely Abo Rawash, Rashid and El Nubaria on yield and fruit quality of 'Samany' date palm cultivar. They revealed that Abo Rawash pollen grains gave the highest fruit weight (28.5 and 35.7g). Rashid pollinizer gave the highest fruit weight in Siwi date palm [32]. The effect of three pollen grain sources namely Giza, Aswan and El-wady El-Gadid on yield and fruit quality of 'Samany' date palm cv. (*Phoenix dactylifera* L.) revealed that the pollination with "Giza" pollen grains exhibited the highest fruit weight [31].

Fruit pulp content

Abdel-Hamid [18] studied six males as different pollen sources for Zaghloul date palm and revealed that Maghal 1, Zaghloul and Hayany males improve the flesh weight percentage. Increased in flesh weight was observed in Malkabi cv. of date palm with Kom-Ambo pollen grains [37]. Al-Hamoudi *et al.* [20] evaluated the some male types as pollinator for Barhi date palm cv. and studies the effect of these pollinators on fruit set and quality of Barhi date palm. Fard pollen produced the highest values for flesh weight (14.90 g and 16.57 g), respectively. Dhakki produce maximum pulp weight when pollinated with male M2, while Zahidi produce the minimum pulp weight with M3 pollens [21]. El-Hamady *et al.* [22] observed maximum flesh weight with M2 pollinator in cv. Hayany. The highest pulp weight (17.01 g and 13.88 g) was observed for trees pollinated with M8 [23]. Farag *et al.* [34] investigated the metaxenic effect of two date palm male pollinizers on physical and chemical properties of cv. Zaghloul. The results proved that pollinizer A (Balteem 14) caused significant increase in flesh weight. Iqbal *et al.* [25] also studied the effect of different *dactylifera* male pollinizer on the pomological traits of Shakri, Zahidi and Dhakki date palm. The maximum pulp weight (10.57 g) was recorded in fruits developed from fertilization of M4 pollens. The influence of twelve pollen sources on fruit production of date palm cv. Barhi revealed that the highest pulp weight (14.5 g) was obtained with Fard no. 4 and lowest (11.8 g) with M12 pollens [26]. Saleh *et al.* [38] reported the effect of different pollen source (male A, B and C) on physical and chemical properties of four female cvs. and they found that male B showed the higher values of pulp percentage as compare to male A and male C. Omar *et al.* [35] reported that the trees pollinated with male M1 pollens cause significant improvement in pulp weight of Khalas date palm. Whereas, Omar and El-Abd [29] observed the maximum pulp weight (23.45 g) in cv. Zaghloul when Meghal 2 pollens were used. Similarly, Rashid pollinizer gave the highest fruit pulp percentage in Siwi date palm [32].

Stone weight

Soliman [37] reported the decrease in seed weight in Bartamoda cv. of date palm when EI-Mansoria and Kom-Ambo pollens were used. Al-Khalifah [19] evaluated the effect of five pollen samples of date palm (*Phoenix dactylifera* L.) on the maternal tissues of fruits in two cultivars, namely 'Barhy' and 'Nabtet-Saif'. In 'Barhy' lower seed-weight was produced by 'Dilim' pollen and in 'Nabtet-Saif' by 'Heet' pollen. But in both the cultivars higher seed-weight was produced by 'Fouzan' pollen. Iqbal *et al.* [23] studied the effect of different *dactylifera* males (M1-M9) and their whorl pollen grains on fruit set, fruit drop and fruit characteristics of 'Dhakki' date palm. They observed that the maximum stone weight (1.37 g and 1.12 g) were recorded when trees were pollinated with M6 in 2007 and M9 in 2008, respectively. Rezazadeh *et al.* [26] examined the influence of twelve pollen sources on fruit production of date palm cv. Barhi and they concluded that the highest seed weight was obtained with Fard no. 4 and lowest with M12 pollen grains. Male A and male C showed the higher values of seed weight as compare to male B in four female cultivars [38]. Omar *et al.* [28] reported the effect of pollen sources on yield and fruit quality of 'Khalas' date palm. The trees pollinated with male M1 pollens cause significant differences in seed weight.

Pulp: stone ratio

Zirari [33] studied the effect of three pollinizers (NP3, NP4 and a Local) on yield and fruit quality of 'Najda' cv. of date palm (*Phoenix dactylifera* L.) and observed that pollination by 'NP3' or 'NP4' significantly improved flesh: seed ratio by 28 per cent as compare to the control. Whereas, 'Nabbut-Ali' and 'Sabbaka' date palm cultivars which are

suffering partial fruit set failure after pollination with 'Hada-10' produced the highest flesh/seed ratio in 'Sabakka' date palm cultivar [24]. Rezazadeh *et al.* [26] examined the influence of twelve pollen sources on fruit production of date palm cv. Barhi and concluded that the highest pulp: seed weight ratio was obtained with Jervis no. 1 and lowest with M10 pollen grains.

Bunch weight

Increased in bunch weight was observed in Hallaway and Khadrawy date palm cvs. when pollinated with Al-Alaam pollinizer [36]. Soliman [37] studied the effect of different pollen types on Bartamoda and Malkabi cvs. of date palm and revealed that Kom-Ambo pollen grains increase the bunch weight. Al-Hamoudi *et al.* [20] evaluated the some male types as pollinator for Barhi date palm cv. and studies the effect of these pollinators on fruit set and quality of Barhi date palm. They observed that Ghanamy pollen recorded the highest significant bunch weights (11.87 and 10.51 kg). Date palm cv. 'Hayany' produced highest bunch weight when pollinated with M1 pollen grains [22]. Iqbal *et al.* [25] reported the effect of different *dactylifera* male pollinizer on the pomological traits of Shakri, Zahidi and Dhakki date palm. They observed that the M1 pollen yielded the maximum average bunch weight of 5.27 kg and 5.00 kg during 2005 and 2006. Noubaria pollen grains gave the highest bunch weight in 'Ahmat' cv. of date palm [27]. Omar *et al.* [28] examined the metaxenic effects of *Phoenix dactylifera* and *Phoenix canariensis* on yield and quality of Khalas fruit. They found that bunches which were pollinated by pollens from *Phoenix canariensis* recorded higher bunch weight. They also reported that the trees pollinated with male M1 pollens cause significant increase in bunch weight in Khalas cultivar. Omar and El-Abd [29] studied the effect of pollinizers (Meghal 1 and Meghal 2) on fruit characteristics of 'Zaghloul' date palm cv. They observed the maximum bunch weight (20.50 kg) when Meghal 2 pollens were used. Rashid and Noubaria gave the highest bunch weight in Siwi date palm as reported by [32]. Omaima *et al.* [30] studied the effect of three different date palm male types namely Abo Rawash, Rashid and El Nubaria on yield and fruit quality of 'Samany' date palm cv. They found that the Abo Rawash pollen grains gave the highest significant bunch weight (kg). The effect of three pollen sources namely Giza, Aswan and El-wady El-Gadid on yield and fruit quality of Samany date palm cv. (*Phoenix dactylifera* L.) and observed that Giza pollen grains significantly increased bunch weight [31].

Induction of doka (khalal) stage

Nixon [39] has given consistent evidences that time of ripening of date fruit may be diversely affected by the pollen used. The possibility of being able to influence the time of ripening by the use of selected pollen, where seasonal margins are rather shortly defined the difference of ten days or two weeks. Abdel-Hamid [18] evaluated six males as different pollen sources for Zaghloul date palm and he found that Maghal 1, Zaghloul and Hayany males gave the earlier fruit maturity. Al-Khalifah [19] evaluated the effect of five pollen samples of date palm (*Phoenix dactylifera* L.) on the maternal tissues of fruits in two cultivars, namely 'Barhy' and 'Nabtet-Saif'. All strains of pollens used in this study had greatly influenced the stages of maturity. The 'Heet' pollen, promoted early maturity of fruits in both cultivars, but 'Dilim' pollen delayed maturity in 'Barhy' and 'Muzahmiya' pollen delayed ripening in 'Nabtet-Saif'. Sudhersan *et al.* [16] observed that the fruit maturity was delayed 15-20 days when Pollen from *Phoenix pusilla* which is closely related to the date palm fertilized the female date palm flowers of three date palm cultivars: 'Barhi', 'Majdool' and 'Sultana'. The effect of three pollinizers (NP3, NP4 and a local male) on yield and fruit quality of 'Najda' date palm cv. (*Phoenix dactylifera* L.) and observed that pollination by 'NP3' or 'NP4' enhance the fruit maturity by 10 days [33]. Rezazadeh *et al.* [26] examined the influence of twelve pollen sources on fruit production of date palm cv. Barhi and concluded that the Jervis No. 1 pollens gave the earliest maturity and M05, M07 and M1 gave the latest maturity of fruits.

Bio-chemical Characters

Chemical composition of fruit varies with the climate, location, stage of harvesting etc. and external appearance such as color, shape and size of fruit are not always good indications of the internal chemical composition. In general, the resultant, palatability, taste and flavor of most fruits are closely related with the chemical composition of the fruit at the time of harvesting. After harvest certain favourable chemical changes take place in the fruit which make it fit for consumption thereby improving its acceptability. A number of studies have been conducted to find out the developmental changes during the growth and maturation of different pollinizers which have been reviewed under the following sub-heads.

T.S.S.

Total soluble solids (TSS) are one of the most important indexes of judging the stage of harvest. In general, most fruits show an increase in TSS during their growth and development. The total soluble solids of fruit pulp generally contain sugar, minerals, acids, *etc.* Soliman [37] observed the increase in total soluble solid content of Bartamoda and Malkabi date palm cultivars when Abou-El-Resh and Kom-Ambo male pollinizers were used. El-Hamady *et al.* [22] reported that 'Hayany' date palm cv. gave higher value (28.5%) at khalal stage, when pollinated with M1 as compare to M2 pollen grains. The effect of two male cultivars on physical and chemical characteristics of Hillawi date palm cv. and they found that fruits produced by Khikri Adi pollens have a significantly higher TSS than fruits produced by Ghannami Akhder [40]. Awad and Al-Qurashi [24] studied the effects of pollinator type and pollination method on fruit set and fruit characteristics of 'Nabbut-Ali' and 'Sabbaka' date palm cultivars. They reported that in 'Nabut-Ali' cultivar, the pollinators 'Hada-8' and 'Hada-9' significantly increased the TSS concentration while in 'Sabakka' cultivar the pollinator 'Hada-8' gave the lowest value. Farag *et al.* [34] investigated the metaxenic effect of two date palm male pollinizers on physical and chemical properties of cv. Zaghoul. The results proved that pollinizer A (Balteem 14) caused significant increase in total soluble solids. The influence of twelve pollen sources on fruit production of date palm cv. Barhi observed that the highest TSS (%) was obtained with M2 pollen grains [26]. Saleh *et al.* [38] reported the effect of different pollen source (male A, B and C) on physical and chemical properties of four female cvs. and found that the fruits pollinated with male B showed higher levels of TSS (%). Mustafa *et al.* [27] studied the effect of pollinizer sources on yield and fruit characteristics of 'Ahmat' cv. date palm (*Phoenix dactylifera* L.). They observed that fruit pollinated with Noubaria pollen source gave the highest TSS percentage. The effect of three different date palm male types namely Abo Rawash, Rashid and El Nubaria on yield and fruit quality of 'Samany' date palm cv. and found that the Abo Rawash pollen grains recorded the highest (27.7%) TSS per cent [30]. The 'Siwi' date palm pollinated by Rashid pollen source had the highest TSS percentage [32]. Omaima *et al.* [31] studied the effect of three pollen grain sources namely Giza, Aswan and El-wady El-Gadid on yield and fruit Quality of Samany Date Palm cv. (*Phoenix dactylifera* L.). They revealed that the palms pollinated with Giza pollen grains recorded the highest value (27.67%) of total soluble solids.

Acidity

Acidity in fruits, present in reasonable limit impart desirable taste and its absence in optimum concentration gives an insipid taste. However, in excess, it may make the fruit unpalatable even if other components are optimum. Organic acids are an important source of respiratory energy. Changes in acidity of fruits may vary according to stages of maturity. Increase in fruit acidity was observed in Malkabi date palm cv. when pollinated with Kom-Ambo pollinizer [37]. Awad and Al-Qurashi [24] studied the effects of pollinator type and pollination method on fruit set and fruit characteristics of 'Nabbut-Ali' and 'Sabbaka' date palm cultivars. They observed that the pollinator 'Hada-5' gave the lowest value (0.42) of acidity in 'Nabbut-Ali' and in 'Sabakka' cultivar the pollinators 'Hada-8' and 'Hada-10' gave the lowest value. The highest acidity was recorded in 'Ahmat' cv. of date palm when Aswan pollinizer was used [27]. Omar *et al.* [28] examined the metaxenic effects of *Phoenix dactylifera* and *Phoenix canariensis* on yield and quality of Khalas fruit. They reported that bunches pollinated by pollen from *Phoenix dactylifera* showed the highest acidity content (0.41%). They also observed the significant differences between males in acidity of 'Khalas' date palm. The palms pollinated by Aswan and New Valley pollinizers produce the highest fruit acidity (0.44) in Siwi date palm [32]. Omaima *et al.* [31] studied the effect of three pollen grain sources namely Giza, Aswan and El-wady El-Gadid on yield and fruit Quality of Samany date palm cv. (*Phoenix dactylifera* L.). They observed that Giza male decrease the acidity level followed by El-Wady El-Gadid male while, Aswan pollen grains recorded the highest value in this respect.

Total sugar

Total sugar is an important factor in determining the palatability of fruits. El-Hamady *et al.* [22] observed that the pollination of 'Hayany' date palm cv. with M1 pollen produce fruits with higher values of total sugar. Abdel-Hamid [18] evaluated six males as different pollen sources for Zaghoul date palm and he found that total sugar was improved when pollinated with Maghal 1, Zaghoul and Hayany. Increase in total sugar was observed in Bartamoda cv. and Malkabi cv. of date palm when pollinated with Abou-El-Resh and Kom-Ambo pollen grains, respectively [37]. Farag *et al.* [34] investigated the metaxenic effect of two date palm male pollinizers on physical and chemical properties of Zaghoul cv. The results proved that pollinizer A (Balteem 14) caused significant increase in total sugar. Saleh *et al.* [38] reported the effect of different pollen source (male A, B and C) on physical and chemical properties

of four female cvs. and found that male C resulted in higher values of total sugar. The effect of pollinizer sources on yield and fruit characteristics of 'Ahmat' cv. date palm (*Phoenix dactylifera* L.) and observed that Noubaria pollens gave the highest value of total sugar [27].

Omar *et al.* [35] examined the metaxenic effects of *Phoenix dactylifera* and *Phoenix canariensis* on yield and quality of Khalas fruit. They found that bunches pollinated by pollen from *Phoenix canariensis* recorded the highest (55.39%) values in total sugar content. They also observed the significant differences between males in total sugar in Khalas date palm. Omar and El-Abd [29] studied the effect of pollinizers (Meghal 1 and Meghal 2) on fruit characteristics of 'Zaghloul' date palm cv. They reported that the palms pollinated with pollens from Meghal 2 showed higher significant percentage of total sugar (28.33% and 28.51%). The 'Siwi' date palm pollinated by New Valley showed the highest value of total sugar (33.90%) [32].

Reducing sugars

Increase in reducing sugars was observed in Bartamoda cv. and Malkabi cv. of date palm when pollinated with Abou-EI-Resh and Kom-Ambo pollen grains, respectively [37]. Wahid *et al.* [40] studied the effect of two male cultivars on physical and chemical characteristics of Hillawi date palm cv. and they found that fruits produced by Khikri Adi pollens have the highest percentage of reducing sugars. El-Hamady *et al.* [22] reported the significant increase in reducing sugars when 'Hayany' date palm cv. was pollinated with M1 pollens. Farag *et al.* [34] investigated the metaxenic effect of two date palm male pollinizers on physical and chemical properties of Zaghloul cv. The results proved that pollinizer A (Balteem 14) caused significant increase in reducing sugars. The effect of different pollen sources (male A, B and C) on physical and chemical properties of four female cvs. found a significant increase in reducing sugars when male A or male C were used [38]. Mustafa *et al.* [27] reported that Noubaria pollens gave the highest reducing sugars in 'Ahmat' cv. of date palm.

Omar *et al.* [35] examined the metaxenic effects of *Phoenix dactylifera* and *Phoenix canariensis* on yield and quality of Khalas fruit in 2011 and 2012. They found that bunches pollinated by pollen from *Phoenix canariensis* recorded the highest (49.53 % and 47.60 %) values in reducing sugar content. They also observed the significant differences between males in reducing sugars in 'Khalas' date palm. The effect of pollinizers (Meghal 1 and Meghal 2) on fruit characteristics of 'Zaghloul' date palm cv. revealed that the palms pollinated with pollens from Meghal 2 showed higher significant percentage of reducing sugars (18.75% and 20.01%) in both seasons, respectively [29]. The 'Siwi' date palm pollinated by New Valley had the highest value of reducing sugars (21.83%) [32].

Non-reducing sugars

Highest non-reducing sugars were observed in Bartamoda and Malkabi cvs. of date palm when EI-Mansoria pollen grains were used [37]. Farag *et al.* [34] investigated the metaxenic effect of two date palm male pollinizers on physical and chemical properties of Zaghloul cv. The results proved that pollinizer A (Balteem 14) caused significant increase in non-reducing sugars. Saleh *et al.* [38] reported the effect of different pollen source (male A, B and C) on physical and chemical properties of four female cvs. and found the significant increase in non-reducing sugars by using pollens male A or male B. Noubaria pollens gave the highest value of non reducing sugars in 'Ahmat' cv. of date palm in 2012 and 2013 [27]. Sarrwy *et al.* [32] examined the influence of different pollen grain sources on yield and fruit quality of 'Siwi' date palm and found that the palms pollinated by New Valley had the highest value (2.07%) of non-reducing sugars.

Conclusion

It is quite evident that the conventional date palm breeding is a time-consuming process and constitutes a laborious task. Crossing the date palm with other Phoenix is of great interest for its cultivation. Indeed, because of metaxenia, the selection of pollen from other species to pollinate females could improve yields, fruit size, quality and even produce seedless fruits. More research and experiments in metaxenia are necessary to assess the effect of different male genotypes and understand the basis of these effects. This could lead to the selection of male cultivars specific to the pollination of given female cultivars. Moreover, other Phoenix appear as genetic reservoirs and hybrid cultivars could be of great interest in terms of cultivation and disease resistance and therefore more research should focus on it. The long term continuity of plant breeding programs and associated researches must be in concordance with the future crop profitability. On the other hand, market niches and production chains must be studied in depth, as a way of avoiding wrong decisions about the crop possibilities.

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