Review Article

ISAH Indian Journal of Arid Horticulture

Year 2021, Volume-3, Issue-1&2 (January - December)

Artificial pollination in date palm: a review

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ARTICLE INFO

Key Words: Date palm, Pistillate Receptivity, Pollination, Pollen storage.

doi: 10.48165/ijah.2021.3.1.1

ABSTRACT

One of the most crucial and time-consuming agronomical procedures in date cultivation is pollination, which is necessary to achieve the required yield. Fruit growth, quality, and yield are greatly impacted by date palm pollen (DPP), which is also highly influenced by pollen structure, viability, and germination capacity. In commercial farming, pollen management involves keeping pollen under refrigeration and combining it with different adjuvants to reduce the amount of pollen needed for pollination. Pollination success is further influenced by female flowers and their receptivity, therefore careful monitoring is essential to notice the timing of anthesis of the female inflorescence. Mechanized tools have made the tedious act of pollination easier, and pollination techniques have improved with time. In addition to aiding in pollination, pollen is also used as a secondary food source for a number of illnesses, including male infertility. The significance of pollen, how to utilize it and potential issues during cultivation are all covered in this article.

Introduction

Dates (*Phoenix dactylifera* L.) are among the world's oldest cultivated fruits and being dioecious, the male and female inflorescences flower on different plants. Although date palms are naturally pollinated by the wind, most commercial date palms are artificially fertilized. Because of the structure, longevity, asynchronized flowering, constant height gain, and prickly leaves of the palm, pollination is one of the most crucial yet time-consuming agronomical procedures in the cultivation of dates. Since the date palm's early domestication, which is estimated to have occurred around 4000 BCE (Zohary and Hopf, 2000), the importance of pollen and its management has been recognized. According to Zaid and de Wet (2002a), the earliest domestication of the crop occurred most likely in the Arabian Gulf region close to its center of origin, Mesopotamia (modern-day Iraq), where the crop was revered. Pollination is a prerequisite for fruit development, and different stages of fruit development are taken into account from the day of pollination. According to Sharma *et al.* (2019, 2021 & 2023) in the absence of adequate pollination, there is a significant risk of abortion or the development of parthenocarpic fruits that are of poor quality and cannot be used or sold. This article discusses the numerous optimizations made to pollination

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Received 05.09.2023; Accepted 08.01.2024

techniques and pollen management over time, from manual application to mechanical use.

Pollination is regarded as one of the most crucial agronomic techniques in cultivation today. Fruits that do not successfully pollinate mature into parthenocarpic fruit, which are small in size and lack desirable commercial traits (Cohen *et al*., 2016). The majority of date palms in the wild groves found in oases and along rivers grow in clusters, with wind acting as the primary means of pollination. However, in order for pollination to be successful, the male and female populations should ideally be 1:1 and closely spaced; this is not feasible for commercial cultivation but does occur in oasis ecosystems (Sharma *et al.*, 2023).The male date palm plants are typically planted in a separate area designated for them, or they are planted alongside farms or roadsides in the majority of commercial date palm orchards across the world. Pollination of approximately fifty female plants is thought to require, on average, one male plant; however, this depends on the quantity of pollen present in each spathe and the number of flowers on the plant (Zaid and de Wet, 2002b).

Fruit set and successful pollination depend greatly on the source and caliber of the pollen. Basically, you can successfully pollinate the flowers with any male date pollen. Nonetheless, it has been observed that the date palm's fruit and seed characteristics are influenced by the pollen's quality called as metaxenia (Abbas *et al*., 2014).

In an ideal environment, enough pollen can flow from the male to the female inflorescences due to the coordinated emergence of the male and female inflorescences. After the initial dusting of male strands on the female inflorescence, hand pollination in traditional methods using two to three male strands placed upside down in the female inflorescence also helps this coordinated synchronization. This method is most popular in most regions of the world (Sharma *et al.,* 2021; Baidiyavadra *et al*., 2019). Pollen management is necessary in two more situations, *viz.* (i) when male inflorescences emerge before female inflorescences, and (ii) when female inflorescences emerge before male inflorescences. In the first instance, pollen is manually collected from the male flowers either by mechanically extracting them or by drying them in the shade. In the second scenario, saved, extracted, and dried pollen from the prior season can be used to make up for the lack of pollen. The pollen is either preserved or used directly for pollination after extraction. It is necessary to pay close attention to the temperature during pollination as well as when the female spathe cracks.

Floral Biology

Flower structure

The date palm is a dioecious species, meaning it has separate male and female flowers that develop in clusters on distinct palms. These clusters of flowers emerge from the leaf axils of the previous year's growth. They can be identified by their distinct morphological characters as listed in Table 1 (adopted from Sharma *et al.*, 2023).

Pollen structure

Pollen, the fine dust-like grain material from male flowers, contains ellipsoidal, bisymmetric, or rhomboid shapes, with dimensions ranging from 17.20–21.40 μm in length and 6.97–10.30 μm in width. Other studies also reported sizes of pollen 20.38–21.94 × 16.32–16.96 μm and 18.56–18.64 × 18.51–18.55 μm (Soliman and Al-Obeed, 2013; Al-Khalifah, 2006).

Pollen viability and germination

In date palm cultivation, successful pollination and fruit set depend more on pollen viability compared to other fruit crops. Pollination success is determined by applying ample

Table 1. Characteristics of male and female flowers of the date palm

	Male Flowers	Female Flowers
Inflorescence colour	Creamy or waxy white	Yellowish white
Spathe character	Short and wide body	Narrow and long body
Inflorescence character	Broom-like inflorescences feature a higher number of strands packed closely together.	Inflorescences are comparatively fewer densely packed with strands
Flower Character	Similar to rice panicles are flowers	Flowers are globose and resemble the seeds of sorghum.
Flower structure	6 stamens, 3 petals, 3 sepals, and 3 carpels make up a flower.	3 sepals and 3 petals make up a flower.
Aroma	It has a unique, pleasant fragrance that attracts insects.	Having a mild aroma, but it doesn't attract many insects.

viable pollen, with viability assessed through tests like acetocarmine staining. The freshness of pollen significantly impacts its germination rate, varying with genotype and inflorescence emergence time. Proper storage is crucial for maintaining pollen viability. The acetocarmine stain method is commonly used to assess viability, with red staining indicating viability. Pollen germination is confirmed through a test involving incubation in a specific medium and microscopic observation of pollen tube germination (Maryam *et al*., 2017). When pollen is fresh, it is most effective and has the maximum germination rate; as it aged, it becomes less effective. The genotype and flower emergence time also affect the quality of the pollen and its capacity to germinate.

Selection of male plant

Selecting the best male pollinators for the commercial female cultivar being produced in a area based on compatibility or optimum results because the male parent's pollen directly influences characteristics like seed size, shape, and colour as well as fruit size, development rate and ripening time in the embryo and endosperm (Sharma *et al.*, 2023; Salomon-Torres*et al.*, 2021). Moreover, synchronization of flowers and amount of pollen produced also accounts for selection of male plants (Helail and El-Kholey, 2000); Rezazadeh *et al*., 2013).

Pollen extraction

The process of pollen extraction from male date palm inflorescences involves careful harvesting during the anthesis period, typically early in the morning to avoid bee interference. Harvesting a day or two before spathe cracking may be done but requires experience. The spathe cover is removed immediately after harvest to prevent moisture, which can spoil the flowers and pollen. The harvested inflorescence is then shade-dried for 3–7 days, avoiding direct sunlight or high temperatures to preserve pollen viability.

Three main pollen extraction methods are employed:

a. **Manual extraction using a sieve**: it is the traditional method where strands are separated, shade-dried, and manually strained to separate pollen from flowers.
b. **Manual extraction by beating**: it involves tying inflorescences upside down to collect flowers and pollen on a base, suitable for handling larger quantities.
c. **Mechanical extraction uses machines**: in this methods machines with a rotating barrel, screen disk, cyclone separator, and suction pump, which efficiently extracts 40% more pollen than traditional methods. This method also reduces direct pollen exposure to growers, minimizing allergy risks.

During shade drying, flower color turns dark brown, but this does not affect pollen quality or quantity. The entire process is crucial for obtaining high-quality pollen for successful pollination in date palm cultivation.

Pollen storage

According to Dennison (1992), pollen can be collected and stored at room temperature (24°C) for up to one month if the male emerges early. Date palm pollen typically lasts for two to three months before it starts to rapidly lose vitality. It is possible to pollinate the female inflorescence with recently collected pollen from the current season when itsfemale inflorescence opens after the male inflorescence (Sharma *et al.,* 2021). If female inflorescence opens early to male, pollen that has been saved from the previous season can be used to pollinate the female inflorescences provided they are stored under refrigeration. Many research hasbeen conducted on theoptimal temperatures to store pollen, with the lowest temperature producing the greatest results. Other temperatures that have been tried include room temperature, 4 °C, -20 °C, and -196 °C. However, keeping at -20°C is typically a better alternative for commercial use due to practical considerations and the unavailability of cryopreservation units. To minimize quality loss from decreased vitality, pollen can be pollinated the same day it is removed from cold storage (Karim *et al*., 2022). A few of the successful experimentation on pollen storage and germination test after period of storage has been listed in Table 2.

Methods of pollination

The period of male and female inflorescence emergence varies due to climatic or agronomicalfactors, however,all the inflorescence do not emerge at a time, thus multiple pollination activities over 3–4 sets may be required to pollinateallbunchesofapalm.Increasedpollenconsumption for pollinating a greater number of inflorescences raises production costs for farmers. Commercial farms often use pre-identified males for pollination, with an average male date palm producing 20 to 30 spathes per season, each yielding 5 to 50 g of pollen. Pollination efficiency is influenced by morning temperatures, with effective time periods reported by various studies in different countries (Slavkovia *et al.* 2016). Date palm pollination broadly occurs through natural, artificial (manual labour), and

Table 2. Length of storage of pollen in relation to different temperatures and their impact on germination

Number	Temperature	Length of storage	Pollen germination (%)	Reference
1.	24°C	Fresh	94.37	Anushma *et al*., 2018
	4°C	2 months	61.64	
	4°C	12 months	0.00	
	-20°C	12 months	73.61	
	-196°C	12 months	90.29	
2.	28°C	Fresh	96.30	Kadri *et al.,* 2021
	28°C	12 months	14.70	
	4°C	12 months	42.10	
	-30°C	12 Months	52.20	
3.	4°C	12 months	24.39	Maryam *et al.*, 2015
	-20°C	12 months	27.40	
	-80 °C	12 Months	24.64	

mechanized methods. A brief of these methods are listed below.

Natural pollination: Natural pollination, common in wild groves or oases, often relies on wind for the process. This method is effective in environments with close planting and nearly equal male and female populations, as seen in natural groves. However, it is not ideal for commercial date palm orchards.Unlike some of the dioecious crops like papaya, where male plants are strategically placed, in date palm cultivation, being a widely spaced plant, it may lead to inefficient wind pollination, impacting overall yield, and potentially resulting in parthenocarpic fruits.

Artificial pollination through manual labour: For commercial cultivation, artificial pollination is the alternative because natural pollination is not a practical method. Date palms have been artificially pollinated for millennia; this practice is not new. Several techniques are covered in the sections that follow.

Using male strands: Attaching inverted male strands to female inflorescences after dusting them with pollen is a widely used technique. If fresh male strands are utilized, this process is simple to follow and works well. But it's expensive, time-consuming, and demands skilled workers.

Using a cotton swab: This technique uses a tiny cotton ball to swab the pre-collected pollen on the female inflorescence. This can be used with pollen that has been saved from the previous season as an alternative to using male strands. It is also time-consuming and expensive, much like using male strands. Alternatively sponge strips can also be used in place of cotton.

Using liquid suspension: This technique involves manually spraying pollen on the inflorescence after mixing it with water or a water-based suspension. If the pollen is blended and sprayed fresh, it works well. For an improved fruit set, the pollen can also be combined with GA_3 at a rate of 20 mgL^{-1} + 10% sucrose (Iqbal *et al*., 2012). For mechanical pollination, a highly pressurized liquid suspension is also used.

Using a cotton cloth bag: This technique involves gathering the dried pollen in the middle of the fabric and tying it off. Because the pollen is tiny, it comes out of the bag when it is dusted on the flower, resulting in pollination. For trees that are taller, a long pole is linked with the cotton bag.

Mechanical pollination

Most commercial orchards use mechanical pollination because it is an efficient method of pollination, increases productivity, overcomes labor shortages, and lowers operating costs (Shapiro *et al.,* 2008 and Mostaan, 2012). Nevertheless, costly techniques might not be appropriate in all situations (El-Mardi *et al.,* 1995).

Mechanized pollen duster/sprayer: Tractor-mounted models with a hydraulic air cannon to blast pollen are among the mechanical varieties. They have up to 22-meter of effective height and can pollinate 350 palms in an hour. They are well-liked in highly progressive nations like the USA and Israel (AGROM, 2020).

Using a hand pollen duster: An inexpensive yet efficient method of pollination, a manual pollinator involves blowing or pumping a tube from the ground level into a bottle carrying pollen to eject pollen dust on the inflorescence; nevertheless, it is not suitable for very tall trees (Sharma *et al.*, 2023).

Motorized pollen duster: Pressurized sprayers are attached to these mechanical devices. Their effectiveness surpasses that of manual pollen dusters, and their 10-meter reach lessens the need for climbing the tree. Each day, they effectively pollinate 150–200 palm trees (Al-Wusaibai *et al.*, 2012).

Electrical pollen duster: A remote control is used to operate the telescopic pole, dispenser, and pollen tank in this model, which is identical to a manual pollen duster. The effort required by humans to climb the tree is effectively decreased (Mostaan*et al*. 2010).

Aircraft: Pollinating date palms with aircraft was one of the techniques employed in the USA in the early 1960s and 1970s, and it is still practiced in some areas of Israel. However, it is ineffective and may lead to a poor fruit set (Cohen and Glasner, 2015).

Artificial intelligence and drones: These tools are made to minimize the amount of pollen needed during pollination as well as the human labour required. Drones equipped with a camera and GPS tracker were developed as part of the One Million Date Palm Trees Project. These drones can operate up to 8 km away and are effective enough to pollinate a significant number of date palms with the least amount of pollen and labour needed (Oman Daily Observ, 2018).

Usage of pollen mixture

To achieve effective pollination, it is essential for the necessary amount of pollen to reach the pistil and form the pollen tube. However, in mechanical pollination, the demand for pollen increases due to limited control over the quantity used per spathe. In situations where pollen is already scarce, it is recommended to mix the dried pollen with a diluting substance to decrease the pollen quantity. A few of the effective dilution and their adulterant are listed in Table 3.

Table 3. Usage of different pollen mixture and methods and its effectiveness in date palm pollination

S. No.	Location	Pollination methods with Treatments	Fruit set (%)	References
1	India	Hand Dusting with Dry Pollen	52.59	Sharma *et al.*, 2021
		Hand Dusting wit Dry pollen + talc (1:9)	49.69	
		Hand Dusting with Dry pollen + talc (1:19)	47.72	
2	Pakistan	Pollen suspension with Liquid pollen (1 g/ L)	74.67	Munir, 2020
		Pollen suspension with Liquid pollen (2 g/ L)	79.67	
		Pollen suspension with Liquid pollen (3 g/ L)	84.5	
		Pollen suspension with Liquid pollen (4 g/ L)	86	
3	Jordan	Hand Dusting with Dry pollen	100	Abu-Zahraand Shatnawi, 2019
		Pollen suspension with Liquid pollen (1g/ L)	72.5	
		Pollen suspension with Liquid pollen (2 g/ L)	81	
		Pollen suspension with Liquid pollen (3 g/L)	81	
		Pollen suspension with Liquid pollen (4 g/L)	91.5	
4	Saudi Arabia	Natural pollination with by wind	26.03	Munir, 2019
		Strands placement hand with 5 strands/ bunch	68.67	
		Hand Dusting with Dry pollen + wheat flour (1:9 ratio)	82.07	
		Pollen Suspension with Liquid pollen (3 g/ L)	85.71	
5	Mexico	Hand Dusting brush with Dry pollen + wheat flour (1:1 ratio)	31.74	Salomon-Torres *et al.*, 2017
6	Saudi Arabia	Strands placement with 2-3 strands/ bunch	69.1	Ben Abdallah *et al.*, 2014
		Strips of sponge with Dry pollen + wheat flour (1:4 ratio)	67.03	
7	Egypt	Hand Dusting with 2 g pollen + 3 g filler material	54.7	Hafez *et al.*, 2013
		Hand Dusting with 1 g Milagro + 4 g filler material	59.20	

Bunch care after pollination

After pollination, success is typically confirmed after 20-30 days. Managing the post-pollination bunch is crucial and depends on the local climate. In areas with mist, rain, or potential low temperatures during flowering or pollination, covering the recently pollinated inflorescence with a paper bag is advisable to maintain a suitable temperature and prevent pollen wash-off (Zaid and de Wet, 2002b). However, extended covering may lead to issues such as fruit etiolation, partial fruit drop, and potential damage from fungus inside the bag (Sharma *et al.*, 2023).

Despite these concerns, covered fruits tend to have less bruising, enhancing their market value. Around a month after pollination, when the fruits reach pea size, thinning is performed to reduce the fruit load and achieve larger ripe fruits, which command higher market value. Thinning methods include removing a third of stands from the inner circle for better aeration, removing a third of strands by length to reduce fruit load and increase size, or manually performing alternative thinning, a labour-intensive practice popular in high-value cultivars like 'Medjool' and 'Barhee'.

Conclusion

Artificial pollination is an indispensable component of date palm cultivation, offering growers the ability to maximize yields, control fruit quality, and overcome the challenges posed by natural pollination methods. This meticulous and resource-intensive process is a key factor in the success of commercial date palm orchards worldwide.

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