Research Article

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Climatic influence on initiation and opening of spathe in date palm (*Phoenix dactylifera* L.) under arid conditions of North Western India

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ABSTRACT

Khadrawy, *Saidy* and *Shamran* are three significant date palm cultivars grown in Jaisalmer, Rajasthan, located in the North Western part of India. These cultivars are primarily consumed in their dried form, known as *Chhuhara*, during the *Doka* stage of fruit maturity. Climatic factors, including temperature, relative humidity, and sunshine hours, play a critical role in spathe initiation and opening in both male and female palms. The data on date to first spathe and its opening in the palm was recorded in the three cultivars consecutively for 6 years from 2008-2013 from 25 Years old plantation located at Chandan Experimental farm of ICAR-Central Arid Zone Research Zone, Regional Research Station, Jaisalmer and correlation was studied with three climatic parameter i.e. temperature, relative humidity and sunshine hours. The investigation revealed that significant effect of temperature (male-3.99e-07**, female-2.05e-08***), relative humidity (male-0.000236***, female-0.00237**) and sunshine hours (male-0.015550*, female-0.01649*) on days taken to first opening of spathe in both the sexes of the palm. Higher relative humidity extends the time required for male spathes to open, while lower humidity levels accelerate the process. This observation highlights the need to investigate the underlying mechanisms and potential interactions between these environmental factors to better understand their influence on spathe development.

Introduction

The date palm (*Phoenix dactylifera* L.), commonly known as *Khajur*, is a dioecious palm native to the Persian Gulf region. Renowned for their nutritional value and high caloric content, dates are a staple crop in many regions. Rich in essential nutrients like iron, potassium, calcium, and fair amounts of protein, copper, magnesium, chlorine, sulfur, and vitamins A, B, and B_2, dates are a valuable dietary addition.

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India, once a leading importer of date fruit, has significantly reduced its reliance on foreign imports as the introduction of commercial date palm cultivars from the Middle East, coupled with advanced tissue culture techniques, has facilitated successful cultivation in arid regions like Gujarat, Rajasthan, Haryana, Punjab, and parts of Tamil Nadu.

Date palm cultivars are categorized based on their ripening season (early, mid, or late) and nature of astringency in the "doka" stage, a crucial period when the fruit begins to ripen and develop its characteristic sweetness. Astringent dates have a high tannin content, which gives them a astringent taste, rendering them inedible as fresh fruit so they are often harvested early and dried to reduce the astringency like in Khadrawy which is typically processed into dried fruits, while non-astringent dates have a low tannin content and a sweet, soft texture, they are often consumed fresh and are popular for their dessert-like quality such as Barhee, Khunezi, Shamran, and Saidy. In India, due to the monsoon season coinciding with the dang stage (when half the dates start ripening), it is a common practice to harvest date fruits at the doka stage (early ripening stage). These harvested fruits are then processed into a dried product known as chhuhara.

Climatic factors, such as temperature, relative humidity, and sunshine hours, significantly influence the initiation and opening of spathes in both male and female date palm cultivars. These factors also affect pollen and stigma receptivity, which, in turn, impacts fruit set and yield. The reproductive floral organs and local climatic conditions play a crucial role in fruit setting and maturation. Flowering initiation and maturity can vary across different cultivation regions, particularly between traditional and non-traditional areas, due to varying climatic factors. Additionally, the physiological characteristics of date fruits and the consistency of abiotic climatic conditions are critical determinants of yield and quality. Understanding the relationship between climatic parameters and spathe initiation and opening is crucial for predicting their impact on fruit set and subsequent yield. Research on flowering behaviour in relation to climate and other environmental factors across various cultivation areas is essential. Synchronous flowering, where both male and female flowers open simultaneously, is ideal for manual pollination. Asynchronous flowering, with a significant time gap between male and female flower opening, requires pollen storage for later pollination if male flowers open earlier. This can impact pollen viability (Sharma *et al.*, 2023; Osman and Soliman, 2002; Khalil, 2015; Kadri *et al.*, 2022; Helail and El-Kholey, 2000; Iqbal *et al.*, 2004; Botes *et al.*, 2009; El-Shafey *et al.*, 2011; Al-Shoaibi *et al.*, 2011; Hachef *et al.*, 2023).

This study focuses on the flowering behaviour of three date palm cultivars: *Khadrawy* (astringent), *Saidy* (non-astringent), and *Shamran* (non-astringent) to understand how climatic factors influence flowering patterns in arid conditions of North Western region of India.

Material and Methods

To investigate the spathe and flowering patterns of the *Khadrawy, Saidy* and *Shamran* date palm cultivars, data was collected from a 25-year-old plantation at the Chandan Farm of the ICAR-Central Arid Zone Research Institute (CAZRI) Regional Research Station (RRS) Jaisalmer. This farm is located at 26.9970277° N latitude, 71.3350833° E longitude, and an altitude of 224 meters. Data on spathe initiation and opening in both sexes of the palm was recorded for six consecutive years, from 2008 to 2013. The dates of spathe initiation and spathe opening were recorded for both male and female flowers. The number of days between these two events was calculated to derive the days to male spathe opening (DMSO) and days to female spathe opening (DFSO). Weather data, including average temperature, humidity, and sunshine hours, was collected from January to March each year using a PAN evaporimeter, thermometer, hygrometer and sunshine recorder installed at the ICAR-CAZRI RRS Jaisalmer. Data analysis was performed using R software (R Core Team, 2024) with packages from the tidyverse ecosystem (Wickham *et al.*, 2023), including readxl for data import, ggplot2 (ggplot2 Team, 2023) for data visualization, and car (Fox, 2008) for ANOVA and post-hoc comparisons. A factorial two way ANOVA model was employed to assess the main and interaction effects of cultivar, average temperature, year, relative humidity, and bright sunshine hours on days to male spathe opening (DMSO) and days to female spathe opening (DFSO).

A mixed-effects linear model was employed to analyze the effects of Cultivar, Year, Avg Temp, RH, and SSH on DMSO. The model was fitted using the lmer function from the lme4 package in R. The random effects included in the model were: Random intercept for Year to account for year-to-year variation, Random intercept for Cultivar to account for variation among cultivars. Fixed effects included Year, Cultivar, average Temperature, RH, and SSH. Model assumptions were checked, including normality of residuals and homogeneity of variance. Post-hoc pairwise comparisons were conducted using the emmeans package to identify significant differences between cultivars.

Result and Discussion

Climatic factors such as temperature, relative humidity, and sunshine hours significantly influence the timing of spathe initiation and opening in both male and female date palms. This study examined the trends in spathe initiation and flowering for the *Khadrawy*, *Saidy* and *Shamran* date palm cultivar over six consecutive years (2008-2013) in the arid North Western region of India. The goal was to understand how these climatic factors affect the pattern of spathe initiation and opening.

Table 1. Mean climatic parameter of the experimental farm at Chandan, ICAR-CAZRI, RRS, Jaisalmer

Year	Temperature January			RH (%)	SSH	Temperature February			RH (%)	SSH	Temperature March			RH (%)	SSH
	Max	Min	Average			Max	Min	Average			Max	Min	Average		
2008	22.5	4.2	13.4	48.1	6.7	27.1	6.0	16.5	41.7	8.5	37.2	16.8	27.0	37.4	8.6
2009	23.0	4.5	15.9	52.5	7.0	28.0	12.8	20.4	49.5	7.8	33.5	17.7	25.6	46.0	7.7
2010	25.4	5.2	15.3	61.3	8.2	30.0	8.5	19.3	58.3	7.7	38.7	17.3	28.0	49.0	9.5
2011	25.1	3.1	14.1	62.0	8.0	27.9	7.9	17.9	58.0	7.4	37.6	9.7	23.6	48.0	8.6
2012	25.1	3.9	14.4	60.2	7.5	27.7	4.7	16.2	55.7	8.2	35.0	12.0	23.5	38.1	8.4
2013	26.3	4.2	15.2	62.9	7.8	30.6	10.0	20.3	50.4	7.5	35.7	13.2	24.4	45.1	8.5
Mean	24.6	6.6	14.7	57.8	7.5	28.6	8.3	18.4	52.3	7.8	36.3	14.5	25.4	43.9	8.6
Std. Dev.	1.5	6.1	0.9	6.1	0.6	1.4	2.9	1.9	6.4	0.4	1.9	3.3	1.9	5.0	0.6
CV (%)	6.0	16.7	6.2	10.5	7.7	4.9	34.7	10.0	12.2	5.2	5.3	22.8	7.3	11.4	6.7

A comprehensive analysis of the correlation matrix reveals a strong negative correlation between temperature and the time taken for both male and female spathes to open. As temperature increases, the time required for spathe opening decreases. The correlation matrix (Fig. 1) indicates a strong negative correlation of -0.87 between temperature and DMSO (days to male spathe opening). This implies that with rising temperatures, the duration for male spathe opening diminishes. In other words, higher temperatures promote a faster opening of male spathes. Similarly, a significant negative correlation of -0.90 (Fig. 2) is observed between temperature and DFSO (days to female spathe opening), indicating that increased temperatures also accelerate the opening of female spathes. These findings align with previous research by Khalil (2015) and Munier (1963, 1980), which demonstrated phenomenal changes on number of days taken to open in both sexes of the palm in the cultivars of this species *Phoenix dactylifera* due to the temperature and its role as a primary factor in controlling on the reproductive phenology behaviour in dates.

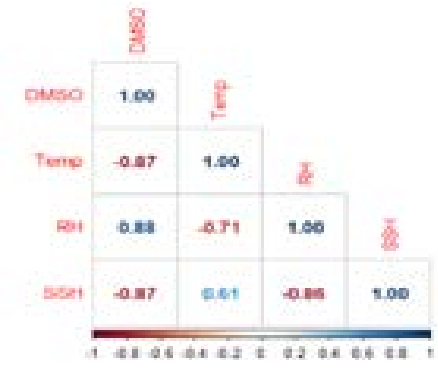

Fig.1. Correlation between DMSO and climatic factors

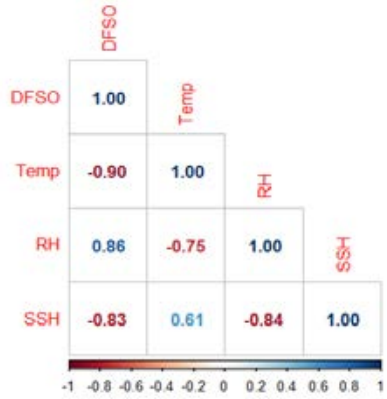

Fig. 2. Correlation between DFSO and climatic factors

Correlation of Relative Humidity (RH) with spathe initiation and opening in date palm

The analysis reveals a significant positive association between relative humidity (RH) and the time taken for male and female spathes to open in all three cultivars studied i.e. *Khadrawy*, *Saidy* and *Shamran*. Higher relative humidity is associated with a longer time frame for male spathe opening, conversely, lower humidity levels can accelerate the opening process. This is supported by a strong positive correlation of 0.88 between RH and Days to Male Spathe

Opening (DMSO), as shown in Fig. 1. For female spathes, the correlation is slightly weaker at 0.86, but still indicates a positive relationship between RH and Days to Female Spathe Opening (DFSO), as depicted in Fig 2. This suggests that increased humidity can also delay the opening of female spathes. Possible explanations for this include slower growth rates in humid conditions, indicating that drier conditions are more favourable for rapid flowering in both male and female plants. Our finding is in conformity to the study carried out by Al-Shuaibi (2012). The finding of a significant correlation between lower humidity and the initiation of flowering in date palms is consistent with studies by Afifa *et al.* (2023). However, relative humidity may not be the sole factor influencing the phenological behaviour of date palms. Its interaction with other climatic factors, such as temperature, may also contribute to the reproductive phase of date palms. The combined interaction effect of temperature and relative humidity is known to trigger the second reproductive cycle in date palms, as reported by Peñuela *et al.* (2019).

Correlation of sunshine hours (SSH) with spathe initiation and opening in date palm

The correlation analysis reveals a significant negative correlation between sunshine hours (SSH) and the time it takes for male and female spathes to open in the cultivars studied i.e. *Khadrawy*, *Saidy* and *Shamran*. A strong negative correlation of -0.83 is observed between SSH and the days to male spathe opening (DFSO), as illustrated in Fig. 1. This indicates that more sunshine hours are typically associated with a shorter duration for male spathe opening. The increase in sunlight may provide the necessary energy and favourable conditions for more rapid development. Similarly, a strong negative correlation of -0.83 is found between SSH and DFSO for female spathes, as shown in Fig. 2. Thus, enhanced sunlight exposure tends to accelerate the spathe opening process for both male and female spathes. The finding in our study is in alignment to the study conducted by Al-Mssallem (2018).

Analysis of Variance (ANOVA) of climatic factors on spathe initiation and opening in date palm

There is no significant effect of cultivars on days taken to spathe initiation and its opening in both male (0.233039) and female palm (0.84035) as depicted in the ANOVA Table 2 and 3. However there is significant effect of temperature (male-3.99e-07**, female-2.05e-08***), RH (male-0.000236***, female-0.00237**) and sunshine hours (male-0.015550*, female-0.01649*) on days taken to first opening of spathe in both the sexes of the palm in all the three cultivars studied. Significant effect of mean temperatures with flower initiation in both sexes of the palm may be due to the recording of fluctuations and the advance shown in the timing of floral initiation from one year to another Afifa *et al.* (2023).

Table 2. Analysis of Variance on date of male spathe opening and climatic parameters

Particular	df	SS	Mean SS	F-value	Pr (>F)
Year	1	4.6	4.6	1.635	0.233039
Cultivar	2	22.3	11.2	3.989	0.057493
AT	1	470.2	470.2	167.966	3.99e-07 ***
RH	1	96.7	96.7	34.544	0.000236 ***
SH	1	24.8	24.8	8.857	0.015550 *
Residual	9	25.2	2.8	-	-

Significant level '***'p≤ 0;
'**' p≤0.01; '*' p≤0.05

df-degree of freedom, SS-Sum of Square, Mean SS-Mean Sum of Square, AT- Average Temperature; RH-Relative Humidity; SSH-Sunshine Hours

Table 3. Analysis of Variance on date of Female Spathe opening (FMSO) and climatic parameters

Particular	df	SS	Mean SS	F-value	Pr(>F)
Cultivars	2	1.0	0.5	0.177	0.84035
AT	1	472.7	472.7	201.189	2.05e-08 ***
Year	1	3.7	3.7	1.313	0.27625
RH	1	43.6	43.6	15.411	0.00237 **
SH	1	22.6	22.6	7.987	0.01649 *
Residual	11	31.1	2.8		

Significance level '***'p≤ 0; '**' p≤0.01; '*' p≤0.05

df-degree of freedom, SS-Sum of Square, Mean SS-Mean Sum of Square, AT- Average Temperature; RH-Relative Humidity; SSH-Sunshine Hours

Conclusion

The findings of the present investigation suggest that temperature and sunshine hours are significant factors influencing the duration of spathe opening in both male and female date palms of the *Khadrawy*, *Saidy*, and *Shamran* cultivars in the North Western part of India. Higher temperatures and increased sunlight appear to accelerate the spathe opening process, while higher relative humidity may delay it. Further research is needed to explore the underlying mechanisms and potential interactions between these environmental factors, which could provide deeper insights into their influence on spathe development.

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Conflict of Interest

The authors have no conflict of interest.

Data Sharing

All relevant data are within the manuscript.

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