



Thermal requirements for the ripening of date palms in Biskra (South-East Algeria). Requisitos térmicos para a maturação de tamareiras em Biskra (Sudeste da Argélia).

[Mohammed Faci](#)¹

¹- Scientific and Technical Research Center for Arid Regions, University Campus, Biskra, 07000, Algeria. E-mail: fm_alg@yahoo.fr

Abstract

The monitoring of phenological stages of date palm and air temperature in Biskra, which is a potential date palm cultivation region in Algeria, during the years 2018 and 2019, has recorded a temporal advancement of the phenological cycle of this plant. This advancement has influenced the dates of harvest, which have become earlier. For their part, the thermal accumulations recorded during the fruiting of the date palm, have experienced an upward trend; they are 3689 to 5141°C, for a base temperature of 10°C. These accumulations are higher, if 7°C is considered as vegetation zero (5170-6835°C). In contrast, the flowering zero recorded in the study area is around 13°C.

Keywords: Sahara. Date palm. Climate change. Temperature. Phenology.

Resumo

A monitorização das fases fenológicas da tamareira e temperatura da do ar em Biskra, que é uma potencial região de cultivo de tamareiras na Argélia, durante os anos 2018 e 2019, registou um avanço temporal do ciclo fenológico desta planta. Este avanço influenciou as datas de colheita, que se tornaram mais cedo. Por seu lado, as acumulações térmicas registadas durante a frutificação da tamareira, registaram uma tendência ascendente; são de 3689 a 5141°C, para uma temperatura de base de 10°C. Estas acumulações são mais elevadas, se 7°C for considerado como vegetação zero (5170-6835°C). Em contraste, o zero de floração registado na área de estudo é de cerca de 13°C.

Palavras-chave: Saara. Tamareira. Alterações climáticas. Temperatura. Fenologia.

Introduction

Global warming, which is a reality observed on the ground, will persist for centuries; according to several authors (MARBAIX, 2018; LESCARMONTIER et al., 2019), it will continue to increase by a rate of 0.2°C per decade. The forecasts of the Intergovernmental Panel on Climate Change (IPCC), predict an average rise of up to 2°C by the end of this century.

This global warming has created a climatic change, which has affected the life dynamics of the majority of living things and their environments (FACI, 2021). For humans, agriculture is considered an economic activity that is expected to be vulnerable to this climate variability; according to Kerveno (2019), agriculture involves natural processes that often require fixed proportions of nutrients, temperatures, precipitation, and other conditions.

Biskra, located in the South-East of Algeria, is a potentially agricultural area; it is known for its vegetable production, fruit and, especially, date products. According to Faci (2021), this wilaya (province) will contain, in the year 2020, 4.44 million palm trees, planted on an area of 44.05 thousand hectares. The number of productive palm trees is 4.36 million, producing 4.77 million quintals of dates, or an average yield of 109.4 kg per palm tree.

Algerian date exports in 2020 exceeded 71 million dollars (APS, 2021a); the majority of these exported dates are produced in the palm groves of the wilaya of Biskra.

The climate of Biskra has undergone a change since the end of the previous century, observed mainly by a decrease in annual cumulative rainfall and an increase in air temperatures; the latter have a direct impact on the vegetative development of the date palm and the ripening of dates (FACI, 2021).

Thermal requirements recorded during fruiting of *Phoenix dactylifera* L. vary according to cultivars, soil-climatic conditions, planting area, cultural practices, etc.; generally, they are higher than 2000 °C (NIXON, 1959; TOUTAIN, 1979; BABAHANI and EDDOUD, 2012).

This modest contribution aims to estimate the zero temperature of the flowering of the date palm and to calculate the thermal requirements for the development of dates in the region of Biskra.

Materials and methods

1. Study area

Biskra is located in southeastern Algeria, about 425 km from the capital Algiers; it is a transition region between a well-equipped North and a deprived South (LALOUANI and ALKAMA, 2013).

The name of the capital of the province 'Biskra' is probably derived from the Roman 'Vescera', synonymous with 'commercial site', because the region was a crossroads between the South, the North, the East and the West. On their part, other historians saw that the first name of the present city was 'Pisciname', designating the 'water source' (DPSB-BISKRA, 2019).

The relief of the study region is divided into four major groups: i) the mountain range and high plateaus, ii) the great plateaus, iii) the plains and steppes and, iv) the depressions (DSA-BISKRA, 2018). This whole is irrigated by a set of wadis that constitute the main water gatherer of the Saharan Atlas; this region has a dense but mostly temporary hydrographic network (MENASRA and BOUZAHHER-LALOUANI, 2019).

The edaphic conditions of Biskra have favored the colonization of certain plant species according to their ecological values and their physiological needs; while the fauna is diversified, we find insects, amphibians, reptiles, birds, mammals, myriapods and crustaceans (NACER and TIAR, 2012).

The region is located in a Saharan bioclimatic stage with hot winters, characterized by low rainfall, recurrent droughts and high summer temperatures (FACI, 2021).

Half of the workforce in the province is employed in the agricultural sector; equivalent to 191233 people, of which 9.25% are women (DPSB-BISKRA, 2019). The cultivation of date palm offered more than 32 thousand jobs in 2021 (FACI, 2021).

The various crops applied are installed on a useful agricultural area (UAA) of 185473 ha, while irrigated agricultural areas represent 62.25% of the UAA (DSA-BISKRA, 2018).

2. Importance of the date palm in Biskra

Algeria has more than 20 million date palms and a production of about one million tons per year, produced by more than 1100 cultivars spread over several regions in the South of the country, of which 3/4 of the date palms are located in the North-East of the Algerian Sahara (TAMRA, 2001 in FACI, 2016; CDARS, 2020; APS, 2021b).

Biskra occupies the first place in Algeria in terms of area occupied by date palms (25.84%), number of palms in production (25.94%) and date production (41.38%); the yield of date palms in the region is the highest on the national level, with an average of 109 kg/tree, while the national average is 68 kg/palm tree (FACI, 2021).

3. Classification of date fruits

The date palm (*Phoenix dactylifera* L.) belongs to the Arecaceae family, where the genus Phoenix contains 12 species. *Dactylifera* is the most important species in terms of commercial value and human food use (ZAID and ARIAS-JIMENEZ, 2002).

Phoenix dactylifera meant, in etymology, the finger of the Phoenicians; because the Greeks considered the date palm as the tree of the Phoenicians (MUNIER, 1973; ZAID and DE WET, 2002).

In general, the fruits of the date palm are classified into: i) dry dates, ii) soft dates and iii) semi-soft dates (MESSAOUDI and TOUAHAR, 2019; FACI and BENZIOUCHE, 2021).

4. Measuring instruments

The measuring instruments used are thermo-hygrometer recorders 'RHT10', of the brand 'EXTECH INSTRUMENTS'; these recorders were installed in four (04) palm groves (Fig. 1), at a height of two (02) meters from the ground. The palm groves concerned are: El-Outaya, Lichana, M'lili and Sidi Okba.

The interval between two measurements was one (01) hour, or 24 measurements per day.

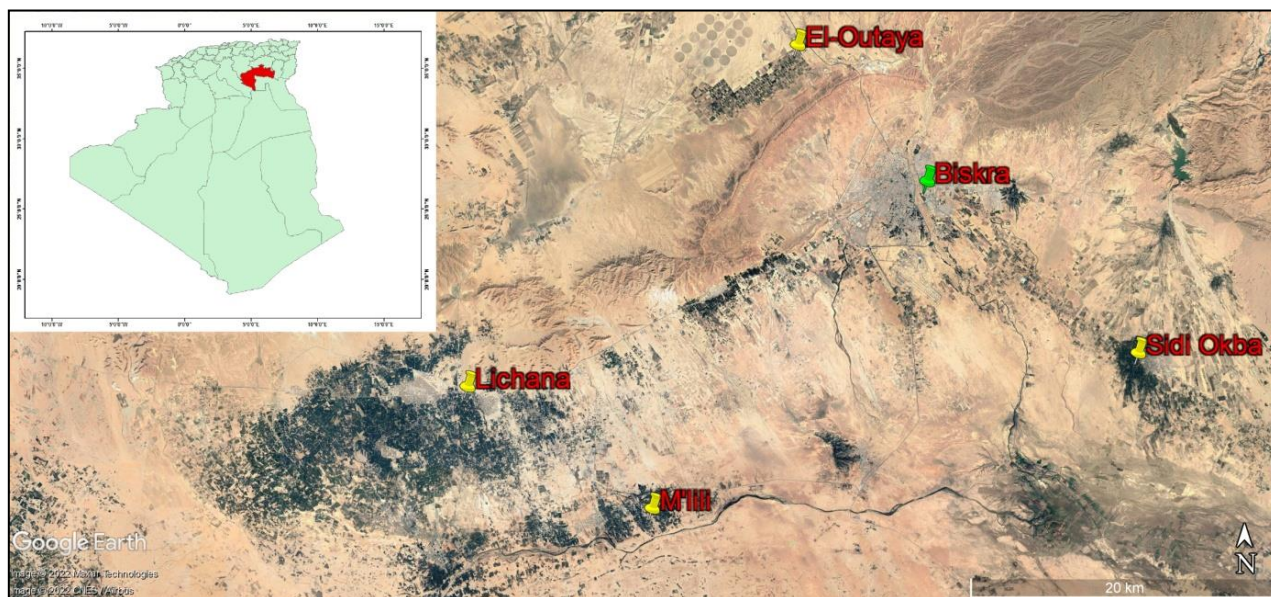


Figure 1 - Location of Biskra province on the map of Algeria (in red) and monitoring sites. Source: CRSTRA, 2018; GOOGLE EARTH, 2022.

5. Monitoring of the vegetative development of date palms

This study focused on the observation and recording of the dates of the beginning of:

- appearance of spathes,
- opening of the spathes,
- pollination,
- maturity of the fruits,
- harvest.

The monitoring targeted three (03) morphologically similar palms of each cultivar, where the seven (07) cultivars are divided into three classes of dates (Table 1):

- Ghars and analogues (soft dates),
- Deglet Nour and analogues (semi-soft dates),
- Degla Beidha and analogues (dry dates).

Table 1 - List of date palm cultivars monitored by study areas during the period 2018-2019.

Classes of dates	Soft		Semi-soft			Dry	
	Ghars	Litima	Arechti	Deglet Nour	Lahloua	Degla Beidha	Mech Degla
El-Outaya	+	+		+		+	+
Lichana	+			+		+	+
M'lili	+	+		+	+		+
Sidi Okba	+	+	+	+		+	+

(+) = Cultivar monitored.

The pollination of the three palms of the same cultivar, in each palm grove, took place in the same day.

6. Base temperature

Temperature is a limiting factor for plant development, the influence of this factor varies from one plant to another; according to Brisson and Levraut (2010), the minimum temperature at which development occurs is called "vegetation zero" or "base temperature". From this temperature, the rate of development increases to a maximum threshold; this threshold varies between species and regions.

Two basic temperatures are considered for this contribution, 7°C and 10°C; because several authors (LOUVET and TOUTAIN, 1973; DJERBI, 1986; SI BENNASSEUR, 2005; BABAHANI and EDDOUD, 2012) consider that the zero of vegetation of the date palm varies according to the cultivar, the area of plantation, the pedo-climatic conditions, the availability of irrigation water and fertilizers, etc.

7. Calculation of degree-day of growth

The growing degree-day is the cumulative temperature during a given period. The calculation of this sum begins after recording temperatures above the base temperature of the species under consideration. According to Kieny (2015), the warmer the weather, the more the plant grows; the degree day of growth is calculated as follows:

$$\text{Daily degree-day} = ((T_{\min} + T_{\max}) / 2) - T_{\text{base}}$$

T_{\min} = minimum temperature of the day (°C).

T_{\max} = maximum temperature of the day (°C).

T_{base} = base temperature (or vegetation zero) of the plant in question.

It is then necessary to make the sum of the degrees days, until obtaining the sum necessary to estimate the total development of a plant, or a part of the plant.

Results

1. Starting dates of some phenological stages and date harvest in Biskra

The bi-monthly monitoring, and weekly during the period of appearance of spathes and maturity of dates, of three palms of the same cultivar at the level of the four (04) sites of monitoring, allowed to record the dates of the appearance and the bursting of the first spathes, the pollination, the maturity and the harvest of dates.

During the two years of monitoring (2018-2019), the appearance of female spathes of soft varieties precedes the appearance of spathes of semi-soft and dry varieties. Generally, the development of spathes begins during the first part of February, except for the dry varieties in the Lichana area (January 27) and the exception recorded during 2019 in M'lili; where the appearance of the first spathes of the soft cultivars began on January 15 (Table 2).

Table 2 - Dates of appearance of female spathes in Biskra.

Classes of dates	Soft		Semi-soft		Dry	
	2018	2019	2018	2019	2018	2019
El-Outaya	February 10	February 10	February 25	February 25	February 25	March 01
Lichana	March 01	March 01	February 01	February 01	January 27	January 27
M'lili	February 01	January 15	February 15	February 20	February 20	February 10
Sidi Okba	February 15	February 15	February 20	February 15	February 25	February 25

The inflorescence of the date palm in Biskra, begins during the first half of March; nevertheless, there are spatial peculiarities, such is the case for the soft varieties of M'lili (the second half of February) and the semi-soft and dry varieties of El-Outaya; which delay until early April (Table 3).

Table 3 - Starting dates of the opening of the female spathes in Biskra.

Classes of dates	Soft		Semi-soft		Dry	
	2018	2019	2018	2019	2018	2019
El-Outaya	March 03	March 03	April 01	April 01	March 15	April 05
Lichana	March 10	March 10	March 05	March 05	March 05	March 05
M'lili	February 25	February 15	March 05	March 01	March 10	March 01
Sidi Okba	March 05	March 05	March 05	March 05	March 10	March 25

In Biskra, date palm growers start the pollination of female spathes during the first half of March (Table 4). However, this operation can be advanced or set back in time, depending on the date of spathe bursting and/or the availability of pollen. Pollination ends, in most palm groves, at the beginning of May.

Table 4 - Dates of pollination in Biskra.

Classes of dates	Soft		Semi-soft		Dry	
	2018	2019	2018	2019	2018	2019
El-Outaya	March 06	March 05	April 05	April 05	March 18	April 07
Lichana	March 10	March 10	March 10	March 10	March 10	March 10
M'lili	March 01	February 20	March 10	March 05	March 15	March 05
Sidi Okba	March 10	March 05	March 10	March 10	March 15	March 25

The complete maturity of dates, at the sites of this study, was recorded from the first dekad of October (Table 5). Except the particularity recorded in 2018, in M'lili and Sidi Okba, where the maturity began during the first dekad of September; but, with a production (fruits) dried. The dry dates take more time to ripen, until November.

Table 5 - Dates of maturity of dates in Biskra.

Classes of dates	Soft		Semi-soft		Dry	
	2018	2019	2018	2019	2018	2019
El-Outaya	October 10	October 10	October 15	October 15	October 30	November 01
Lichana	October 10	October 10	October 10	October 10	October 10	October 10
M'lili	October 10	October 20	September 05	October 10	October 10	October 01
Sidi Okba	October 05	October 05	September 10	September 25	October 25	October 15

The harvest of dates, in Biskra, is operated during the period October-November of each year (Table 6); it is dependent on the period of maturity of dates and / or the availability of skilled labor. It should be noted that in some date palm gardens, the harvest is advanced temporally to September, where farmers cut the bunches of dried dates (premature).

Table 6 - Dates of the harvest of dates in Biskra.

Classes of dates	Soft		Semi-soft		Dry	
	2018	2019	2018	2019	2018	2019
El-Outaya	October 20	October 15	October 15	November 15	November 15	November 10

Lichana	November 10	November 10	November 10	November 10	November 10	November 10
M'lili	October 10	October 20	September 20	October 20	November 10	October 20
Sidi Okba	October 10	October 10	November 01	September 25	October 25	October 20

2. Duration of the development cycle of the date from the date of appearance of the female spathes

The duration of the phenological stages of date palm in Biskra varied according to the cultivar and the environmental conditions of the growing season (Table 7). In general, the duration from:

- the appearance to the opening of the female spathes is from 9 to 37 days; except for the exception which affected the variety Mech Degla, in 2019, in El-Outaya (55 days).
- the opening of the female spathes to the pollination, does not exceed one week; there are farmers who carry out the pollination the same day of the opening of the female spathes.
- the appearance of the female spathes to the maturity of the dates, requires 202 to 278 days.
- the bursting of the female spathes to the maturity of the dates, requires 184-260 days.

Table 7 - Duration of the development cycle of the date from the appearance of the female spathes of the date palm in Biskra (in days).

Classes of dates	Soft		Semi-soft			Dry	
	Ghars	Litima	Arechti	Deglet Nour	Lahloua	Degla Beidha	Mech Degla
Duration between the appearance and the opening of the female spathes							
2018	9-24	13-18	/	13-35	18	13-37	4-18
2019	9-31	23-28	18	13-35	9	26-37	4-55
Duration between the opening of the female spathes and pollination							
2018	0-5	5	/	4-5	5	3-5	3-5
2019	0-5	5-7	5	4-5	4	0-5	0-6
Duration between the appearance of the female spathes and the maturity of the dates							
2018	223-251	232-242	/	202-273	202	242-256	223-247
2019	223-278	247-263	222	232-251	232	232-256	223-259
Duration between the opening of the female spathes and the maturity of the dates							
2018	214-227	214-229	/	189-260	184	219-229	214-229
2019	214-247	224-235	204	197-224	223	204-219	204-219

3. Duration of the fruiting cycle

The duration of the fruiting cycle in Biskra, from the date of pollination, varied between 184 and 230 days (Table 8). Two exceptions of lengthening duration were recorded in M'lili, the first in 2018, for the variety Deglet Nour (255 days) and the second in 2019, for the variety Ghars (242 days).

Table 8 - Duration of the fruiting cycle of the date palm in Biskra (in days).

Classes of dates	Soft		Semi-soft			Dry	
	Ghars	Litima	Arechti	Deglet Nour	Lahloua	Degla Beidha	Mech Degla
2018	209-223	209-224	/	184-255	223	214-226	209-226
2019	214-242	219-230	199	193-219	219	204-214	198-214

4. Base temperature of flowering

Often, the appearance of spathes begins after the air temperature starts its upward trend, frequently from January; throughout the period of increasing temperatures (February-April), the spathes burst (FACI, 2021).

The average air temperature above which the appearance of female spathes begins in Biskra is generally around 13°C. If we consider the 10 days preceding the appearance of the first female spathes, it varied between 12.06 and 14.02°C for soft varieties, 11.11 to 13.48°C for dry varieties and 10.55-15.35°C for semi-soft varieties (Table 9).

Table 9 - Average temperatures of the flowering of the date palm in Biskra (in °C).

Classes of dates	Soft		Semi-soft			Dry		
	Ghars	Litima	Arechti	Deglet Nour	Lahloua	Degla Beidha	Mech Degla	
2018	Before 30 days	11.28	11.93	/	11.87	13.82	11.90	11.90
	Before 10 days	12.06	13.15	/	12.40	12.97	13.16	13.15
	Before 01 day	10.05	12.50	/	10.55	11.75	10.08	10.08
2019	Before 30 days	12.40	13.67	14.12	11.57	15.35	11.65	13.66
	Before 10 days	14.02	13.40	15.03	12.62	13.83	11.11	13.48
	Before 01 day	11.75	12.60	11.75	11.00	13.40	11.20	14.25

5. Thermal requirements of the maturation of dates in Biskra

The thermal accumulations presented in Tables 10 and 11 are the ranges of variability of accumulations, in degree-days, in the region of the present study; the average of the totals of the three palms of the same cultivar in each site represents the thermal requirements necessary for the ripening of the date fruits in the palm grove considered.

In order to calculate the thermal requirements, two basic temperatures were chosen (7 and 10°C) and two dates were fixed: i) the date of appearance of the female spathes, and ii) the date of pollination.

Temperature accumulations from 7°C, as a base temperature, vary between:

- 4942 and 7362 degree-day, from the date of appearance of the female spathes.
- 5170 and 6835 degree-day, from pollination.

The thermal requirements for the ripening of dates, starting from 10°C as a basic temperature, are from:

• 3930 to 5416 degree-day, from the date of the appearance of the female spathes; nevertheless, the thermal requirements of ripening of the semi-soft fruits are less high compared to the other categories of dates.

- 3689 to 5141 degree-day, from the date of pollination.

Table 10 - Thermal requirements for the ripening of dates in Biskra (in degree-day), considering 7°C as basic temperature.

Classes of dates	Soft		Semi-soft			Dry	
	Ghars	Litima	Arechti	Deglet Nour	Lahloua	Degla Beidha	Mech Degla
From the date of the appearance of the female spathes							
2018	6267-6521	6297-6593	/	5482-7098	5344	6593-6912	6297-6606
2019	5791-7362	6419-6895	5568	5957-6913	4942	5878-6982	5878-6872
From the date of pollination							
2018	5874-6334	5859-6744	/	5170-6773	6585	6243-6334	5859-6334
2019	5537-6835	5844-6417	5212	5636-6330	6378	5381-6330	5401-6330

Table 11 - Thermal requirements for the ripening of dates in Biskra (in degree-day), considering 10°C as basic temperature.

Classes of dates	Soft		Semi-soft			Dry	
	Ghars	Litima	Arechti	Deglet Nour	Lahloua	Degla Beidha	Mech Degla
From the date of the appearance of the female spathes							
2018	4650-4960	4673-4899	/	4068-5187	3930	4877-5120	4673-4690
2019	4167-5416	4578-5166	4014	4298-5156	4961	4254-5190	4254-5059
From the date of pollination							
2018	4411-4836	4396-4675	/	3882-4988	3689	4663-4836	4396-4836
2019	4039-5141	4234-4884	3819	4132-4832	4845	3953-4832	3953-4832

Discussion

Winter temperature has a direct impact on pollen growth and development and spathe opening; according to Ouda Ibrahim and Zaid (2019), warm winters and early summers reflect on spathe appearance dates and date ripening. According to the same authors, the appearance of spathes begins in February. It was the same in Biskra, except for the peculiarities recorded in the sites of M'lili (in 2018, for soft varieties) and Lichana (in 2018 and 2019, for dry varieties), where the appearance of spathes began during the second half of January.

Several authors have agreed that the zero of flowering of date palm is 18°C (SWINGLE, 1928; BOUNAGA, 1991; ZAID and De WET, 2002; OUDA IBRAHIM and ZAID, 2019), however, the average air temperature that precedes the appearance of spathes in Biskra oscillates around 13°C. The results recorded during the realization of the present study are lower than those quoted by several previous studies, because the average temperatures preceding the appearance of the spathes, in Biskra, vary between 11.11 and 15.35°C.

In the region of the present study, the opening of the spathes begins only from the second half of February; whereas the protectors of date palm begin the operations of pollination from the third decade of February. According to Sedra (2003), who considers that date palm pollination takes place during the March-May period, he recommends applying pollination 5 to 7 days after the opening of the female spathes. It should be noted that some farmers in Biskra carry out manual pollination during the first day of opening of the female spathes, without waiting for the natural (normal) opening of the spathes.

Generally, dates ripen during the period between July and November (SEDRA, 2003; OUDA IBRAHIM and ZAID, 2019), while these fruits will reach full ripening, in Biskra, from September to November. Therefore, the harvest of date bunches is spread from late September (early and / or dried) to late November.

Globally, the maturity of dates requires 120 to 240 days (OUDA IBRAHIM and ZAID, 2019); while the present study, conducted in the region of Biskra, found that the duration of the fruiting cycle varied between 184 to 255 days.

According to Faci (2021), the thermal requirements for the maturity of dates in Biskra vary according to the areas of plantation and depending on the conditions surrounding the palm groves (climatic, pedological, fertilization, availability and quality of irrigation water, age and maintenance of the palm trees, etc.). This study, conducted in 2018-2019, found that the thermal accumulations necessary for the complete maturity of dates are 3689 up to 5141°C, if we consider that the zero of vegetation of the date palm is 10°C; on the other hand, in case of setting the threshold of 7°C as base temperature, the accumulations are 5170 to 6835°C. Contrary to the results recorded in Biskra, several

researchers have announced that the thermal needs, for a good quality, vary between 1550 and 3500°C; according to the geographical localization, the precocity of maturation and the classes of dates (NIXON, 1959; TOUTAIN, 1979; BABAHANI and EDDOUD, 2012; OUDA IBRAHIM and ZAID, 2019).

The increase in thermal accumulations is the consequence of the excessive increase in air temperatures on the region of Biskra; this increase, which has known a rise of more than 1°C during the last thirty years (and may reach up to 4°C by the end of this century), has a negative impact on the quality of dates (desiccation of fruits, accumulation of sucrose, early maturity, etc.) (FACI, 2021). Therefore, the negative repercussions may be more serious, because the trend towards higher air temperatures will persist until the year 2100.

Conclusions and recommendations

This study focused on the monitoring of the phenological cycle of seven date palm cultivars, classified into three categories of dates: soft, semi-soft and dry, in four palm groves in the region of Biskra, which is the first producer of dates in Algeria.

Continuous observation during two agricultural seasons, 2018-2019, showed that the appearance of spathes begins from the end of January, while the opening of spathes begins in late February. Therefore, the producers of dates, who carry out the pollination manually, begin this operation at the beginning of March.

The complete maturity of the fruits begins in September, whereas the harvest of the bunches of dates begins at the end of September; this operation knew a temporal advance, following the desiccation of the dates, accelerated by the rise of the air temperatures. In the study area, the time required for the maturity of dates varied between 184 and 255 days.

The recording of air temperatures inside the palm groves, has shown that the average temperature appropriate for the beginning of flowering of the date palm, in Biskra, is in the vicinity of 13 ° C. However, the thermal accumulations recorded during the period of ripening dates are higher than 3689 ° C; these accumulations are higher than the needs necessary for a good ripening of dates.

The temporal advancement of the phenological stages and the harvesting period of dates, in Biskra, and the increase of air temperatures in the region, require the adaptation of all the agricultural conduct of this plant species, as well as multiplying the researches, in order to adapt with these changes; which can harm the date production, qualitatively and quantitatively.

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Conflicts of interest

There is no conflict of interest with anyone.

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