

Sustainable oases agriculture: A journey through Morocco's date palm production system

Kaoutar Hamriri*^{1,2)} , Majid Atmani¹⁾ , Ali Abidar²⁾ , Larbi Aziz²⁾ ,
Mustapha Fagroud³⁾ , Rachid Bouamri⁴⁾ 

¹⁾ Sidi Mohamed Ben Abdellah University, Faculty of Science and Technology,

Laboratory of Functional Ecology and Environmental Engineering, B.P. 2202 Imouzzer Rd, 30000, Fes, Morocco

²⁾ National School of Agriculture, Department of Rural Development Engineering, B.P. S/40, km 10, Haj Kaddour, 50001, Meknes, Morocco

³⁾ National School of Agriculture, Department of Agronomy, B.P. S/40, km 10, Haj Kaddour, 50001, Meknes, Morocco

⁴⁾ National School of Agriculture, Department of Plant and Environment Protection, B.P. S/40, km 10, Haj Kaddour, 50001, Meknes, Morocco

* Corresponding author

RECEIVED 09.08.2023

ACCEPTED 04.10.2023

AVAILABLE ONLINE 31.12.2023

Abstract: In the heart of Moroccan oases, date palm trees stand as the lifeblood of local communities, serving as both a livelihood cornerstone and a dietary treasure trove. Morocco has long been a leading date fruit producer. Yet, amidst the palm groves, several environmental, technical, and socio-economic challenges have threatened the sustainability of this ancient crop. This study assesses the constraints and limitations of the date palm production system in Tafilalet oases that have kept this crop from reaching its full potential. A total of 56 producers were interviewed using an open-closed survey, illuminating interviews with key informants, dynamic focus group discussions, and direct observations in palm groves. The findings reveal that primary restrictions and barriers impeding the progress of this sector are: producers' moderate education level and the limited adoption of technological innovation, few opportunities given to young producers, palm groves' fragmentation, poor management of date fruits, low imports of the necessary inputs (fertilisers, irrigation, etc.), and the poor organisation of the marketing circuit (storage and packaging). Advocate renewed commitment to preserve and modernise palm groves, blending heritage with modern practices for thriving, sustainable date palm production. It is entirely conceivable to produce organic dates in the region since producers use a few quantities of chemical products, notably fertilisers and phytosanitary products.

Keywords: date palm tree, oasis, palm grove, producer, production system, sustainability

INTRODUCTION

Date palm (*Phoenix dactylifera* L.) is a fruit tree constituting the principal horticultural crop in the oasis ecosystems (Lemlem, Alemayehu and Endris, 2018). It has adapted to areas with long dry summers and mild winters (El-Juhany, 2010). It has a unique characteristic to thrive in deserts where temperatures could be high, and it can tolerate a high level of salinity (Hussain, 2010). Throughout history, the date palm has held a significant place in people's lives (Chandrasekaran and Bahkali, 2013). Cultivated for over 4,000–5,000 y in the Arabian Peninsula, Middle East, and North Africa, this crop has deep historical roots (Tengberg, 2012).

Interestingly, the date palm tree thrives in both the Old World (including the Near East, North Africa, and Spain) and the New World (such as Australia, continents of North America and South America), where dates are commercially grown in substantial quantities (Zabar and Borowy, 2012). Based on the statistic of the Food and Agriculture Organization corporate statistical database (FAO, 2014), the Arab countries play a central role in date palm production, hosting 71% of the 140 mln date palms cultivated in 34 countries worldwide and contributing to 96% of the total date production. Notably, Egypt, Iran, and Algeria are the leading global date producers, yielding 1.4, 1.1, and 0.9 Tg respectively. In comparison, although Morocco ranks 6th in terms of cultivated

area, producing 58 thous. ha, it is positioned at the 12th spot in production, with an output of fewer than 0.1 Tg (FAO, 2014).

Date palm cultivation aims to be a catalyst for the development of Moroccan oases (Ouabouch, 2018). However, since the beginning of the 21st century, the situation of date palm production, in Morocco, has undergone a drastic change. From the 15 mln date palm trees that inhabited the south Atlas oases, the majority of which were represented by good cultivars, there are only 4 mln trees, much of which are seedlings of variable and low quality, and thus the total area of the oases has been reduced from about 150 thous. to 44 thous. ha (Saaïdi, 1992). This degradation is due to various environmental, technical, and socio-economic constraints (Zabar and Borowy, 2012). Oasis areas, susceptible to the impacts of climate change and irrational human exploitation (Chelleri *et al.*, 2014), have witnessed environmental degradation due to natural factors like drought, salinity, bayoud disease, and a lack of rehabilitation initiatives (Botes and Zaid, 2002; Meddich *et al.*, 2018). The spread of bayoud, the main cause of this decline, has been deteriorating Moroccan palm groves at a rate of 2 to 4% each year, having already decimated over 65% of the country's palm trees, making export unfeasible (Essarioui and Sedra, 2017). Furthermore, the limited availability of water resources for irrigation and the recurring extended periods of drought are factors that have played a substantial role in this decline, either directly or indirectly (El Khoumsi *et al.*, 2014). Persistent droughts have caused the partial dehydration of over 500 thous. palm trees (Renevot *et al.*, 2009). Water table levels were significantly lowered which provoked the drying up of wells and khattara (El Khoumsi *et al.*, 2014). The combination of all these factors contributes to the abandonment of several lands and the scarcity of labour. In addition to the above factors, there are other problems like ageing plantations, salinisation, and desertification, which are present in Tafilalet under the influence of climate change and improper land human activities (Belarbi *et al.*, 2004; El Khoumsi *et al.*, 2014).

Multi-purpose surveys regarding the date palm were carried out in different countries worldwide (Rabou and Radwan, 2017). The research conducted in Morocco primarily emphasised the identification of cultivars, the significance of date palm utilisation,

as well as the study of pests and diseases affecting date palms. However, only limited attention has been given to evaluating the existing production system of date palms. In this context, this study assesses the constraints and limitations of the date palm production system in Tafilalet oases that have kept this crop from reaching its full potential.

MATERIALS AND METHODS

STUDY CONTEXT

Our study was part of a research-development project, named "Application of organic bio-fertilizer technology to improve the sustainability of date palm production and cultivation", aiming to establish and introduce a new biotechnological innovation (biofertiliser based on compost) in the oases of Errachidia, localised in Tafilalet region (Southeast of Morocco). In this regard knowing the actual production system of date palm in the oasis is an essential step to introduce this biotechnological innovation.

STUDY AREA

In the Tafilalet region, agriculture remains the main economic activity (about 90%) for an average of 663,700 inhabitants, among which 66.8% are rural. It is characterised by a semi-arid climate defined by an average annual precipitation of 265 mm in the north and 60 mm in the south, and temperatures ranging from -1.5°C in January to 50°C in July (ORMVA-TF, 2016). Tafilalet region is considered as one of the important regions of date palm production in Morocco, since, 85% of the total dates are produced in it (MAPMDREF, 2015). A total of 1.9 mln palm trees were planted in an area estimated at 48,305 ha, producing an average of 34 Gg, precisely an average of 30.5 kg-palm⁻¹ (ORMVA-TF, 2016). Tafilalet region comprises five provinces, including the province of Errachidia which alone produces 35% of the total regional dates production (MAPMDREF, 2015). The study was conducted in three sites located in this province, exactly on the municipalities of Erfoud, Tinejdad, and Jorf (Fig. 1).

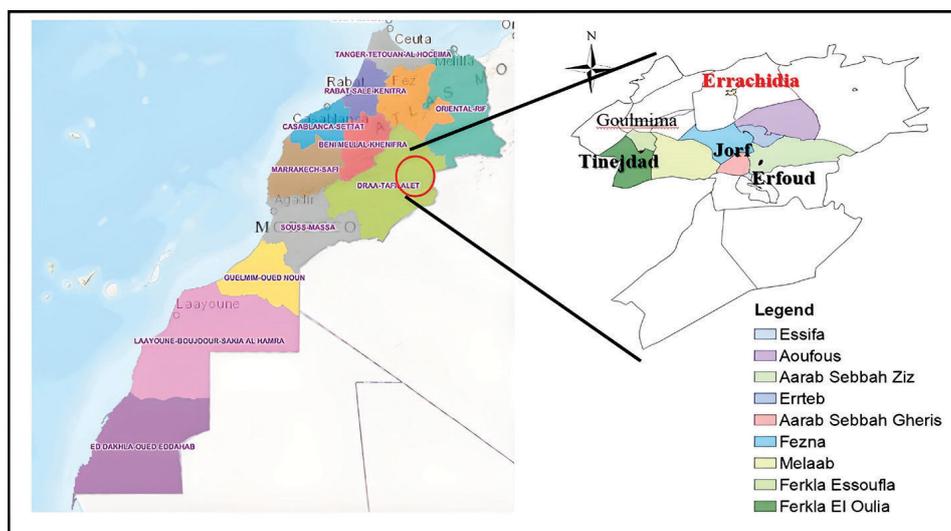


Fig. 1. Representation of the study area; text in black marks the primary information collecting sites, text in red marks the localisation of Errachidia Province where the secondary information were collected from the ORMVA-TF; source: own elaboration based on Google Earth pro and ArcGIS software (no date)

DATA COLLECTION

A structured survey comprising both open-closed questions was formulated using information gathered from agricultural institutions and bibliographic research. From April to May 2017, face-to-face interviews were conducted with 56 date palm producers affiliated with professional agricultural organisations such as Economic Interest Groups (EIG), cooperatives and associations, located in Erfoud, Tinejdad-Goulmima, and Jorf (Fig. 1). Each interview lasted for 30 to 40 minutes on average. The survey was pretested with 10 producers. It was adjusted accordingly to deeply understand the date palm production system employed in those regions. The primary aspects addressed in the survey were included: 1) details information about producers; 2) assessing the oasis production system, such as its size, intercropping crops, irrigation system, density, and date palm cultivars; 3) examining the technical aspects of date palm production system, such as the timing and the frequency of each operation; 4) investigating the methods employed for harvesting and marketing.

DATA ANALYSIS

The data collected were organised and coded into numerical values, tabulated in Excel (Microsoft Office 2016), and descriptively analysed using statistical package for social sciences (IBM SPSS 20) which is a computer program version 20 for Windows. The most important variables were the technical production of date palm trees: tillage and weeding, irrigation, organic fertilisation, mineral fertilisation, pollination practices, frond pruning, date fruit management, plant protection, harvest, and marketing. These practices are compared to the production norms recommended by researchers.

RESULTS AND DISCUSSIONS

PRODUCERS CHARACTERISTICS

Age distribution

The majority of the interviewed producers were aged over 51 years old, while only 4% of them were below 30 years old. Those between the ages of 41 and 50 accounted for 32% of the total sample, whereas the category of 31 to 40 years old represented 14% of the respondents (Tab. 1). The age distribution observed in the study area aligns with the statistics provided by the High Commission for Planning (Fr.: HCP – Haut Commissariat au Plan) for Morocco. According to their estimates, the average age of producers in Morocco is approximately 52 years old, with the age groups of 65 and 35 constituting 23% and 13% respectively (HCP, 2011). The age of the surveyed population is growing, along with the patriarchal structure found among producers in the area. Producers do not easily transfer their oasis's control to their sons. The production of dates palm is considered one of the hardest crops cultivation in the oasis area, which necessitates physical strength and sageness in action and good expertise in date palm production. The crop production and management of date palms is hard work that requires physically and mentally mature personnel (Lemlem, Alemayehu and Endris, 2018). This act gives less freedom and opportunity to young producers, who have more ability to adopt new technologies and can be innovative more than their ancestors to develop and enhance the productivity of date palm trees.

Table 1. Characteristics of producers' age and education level

Variable	Category	Frequency (<i>n</i>)	Ratio (%)
Age (y)	≤30	2	4
	[31–40]	8	14
	[41–50]	18	32
	≥51	28	50
Education level	illiterate	6	11
	quranic or primary	6	11
	secondary	18	32
	high school	18	32
	university	8	14

Explanations: *n* = number of occurrences.

Source: own study.

Education level

The survey revealed that most of the producers interviewed possessed a moderate level of education. An equal proportion of 32% of producers had completed secondary or high school education, and, 11% of them either had no formal (illiterate) education or had only completed primary school (Tab. 1). Education plays a vital role in fostering a deep understanding and effective application of advanced agricultural techniques and technology. According to Ekwek, Nwachukwui and Ironkwea (2009), education is the most important tool to bring about changes in human behaviour and thus to implement the recommended agronomic practices of crops that are important for the improvement of production and productivity. Furthermore, the level of education plays a significant role in shaping the farmers' capacity to assess the innovations and technologies being introduced to them (Rahim, Sadiq and Mahmood, 2003).

OASIS PRODUCTION SYSTEM

Farm size

As presented in Table 2, the total agricultural area covered 256 ha, with individual farms ranging from less than 1 to 14 ha, and an average farm size of 5 ha. Based on the collected data, the farms were categorised into three groups: small farms (≤5 ha) accounted for 73% of the total area, medium farms (6–10 ha) represented 14%, and big farms (≥11 ha) constituted 13% (Tab. 2). The division of land through the inheritance system has led to the

Table 2. Farm size in the study area

Farm size	Frequency (<i>n</i>)	Percentage	Area (ha)	
			total	average
Small (≤5 ha)	40	73	122	3.05
Medium (6–10 ha)	9	14	95	10.55
Large (≥11 ha)	7	13	39	5.57

Explanations: *n* = number of occurrences.

Source: own study.

farms' fragmentation, resulting in smaller farms. This fragmentation has emerged as a significant socio-economic obstacle, hampering the progress of date palm production. This issue was highlighted by Ait Hmida (2003), who also pointed out that such fragmentation not only affects date palm production but also hinders the growth of other crops cultivated within the oases. The division of oasis farms poses challenges for producers to increase their income and offers limited opportunities for young producers to explore and innovate in the agricultural domain. According to Belarbi *et al.* (2004), a farmer, on average, owns 10 separate plots scattered at a distance from one another. This dispersion of resources and energy discourages investment in agricultural production by the producer's sons.

Intercropping system

In the Tafilalet oases, like many other oases in other region, the production system is structured into two or three strata. The date palm trees form the upper stratum and protect from excessive insolation the fruit trees (figs, almonds, olives, pomegranates, etc.), and the arable crops (barley, wheat, sorghum, alfalfa, and various vegetables) of the two lower stratum, hence contributing to the formation of a mild microclimate (El Khoumsi *et al.*, 2017; Garbati Pegna *et al.*, 2017b). In the study area, 61% of producers practice cultivation across all three strata, while 32% of producers opt for two strata. The remainder of the producers choose to cultivate only date palm trees in their palm groves (Fig. 2). Date palm trees create a favourable microclimate that benefits the intercropping thrive within the oasis ecosystem. Consequently, intercropping within date palm groves can lead to increased agricultural productivity and sustainability. Producers, in the study area, cultivate olive trees, fig trees, pomegranate trees, wheat, lucerne, etc. This traditional producers' strategy enables them to increase their incomes and fulfil their food requirements, and alimentation of livestock farming.

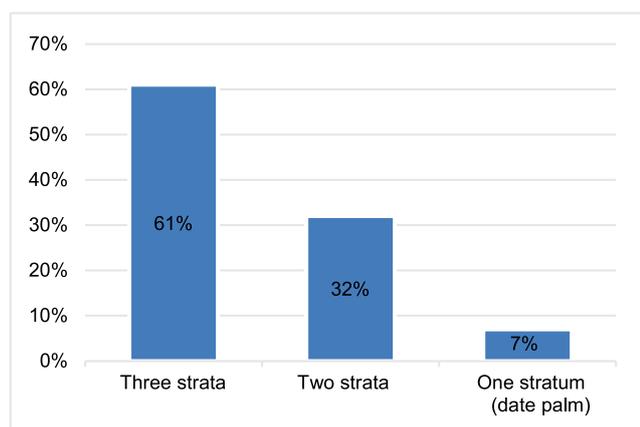


Fig. 2. Representation of the strata system; source: own study

Indeed, the closely spaced planting in the oasis area can establish a beneficial microclimate, supporting the successful growth of crops and providing protection against the effects of climate change. Nonetheless, the limited spacing between crops can lead to competition for nutrients, negatively affecting the production and productivity of dates and other crops. Furthermore, this close arrangement can facilitate the spread of certain diseases like bayoud. Additionally, due to the disorganisation of cultivation, producers may not be able to fully exploit their farms'

potential efficiently. Lemlem, Alemayehu and Endris (2018) emphasised that when fruit trees are planted closely together, the competition for nutrients, moisture, and space intensifies. Adding this proximity, also leads to self-shading, diminishing light absorption by the leaves, ultimately hampering photosynthesis and, consequently, reducing fruit tree production and productivity. Producers need to organise their oases in order to reduce enemies' propagation and get all ecological and economic benefits.

Irrigation method

Producers in the oases use a typical irrigation system. Irrigation by submersion is the most commonly used method by producers (66%) for bringing water from underground to the traditional (earthen) or modern (concrete) canals "saquias". For them, irrigating all intercropping crops planted under date palm trees is the most suitable method. However, this system leads to water losses by percolation and evaporation due to the high temperature, and it can be one of the causes of disease propagation (Belarbi *et al.*, 2004).

The new method of drip irrigation seems to be the most adequate method for date palms in actual conditions, but its technical installation is very costly for small producers. Even so, 20% of the producers adopted it, and 14% started to slowly convert to the new irrigation system, due to the high installation price (Tab. 3). This signifies the Moroccan Government's dedication to promoting the adoption of water management practices like drip irrigation among producers. However, based on the observations made during the farm visit, the management of these systems cannot be considered successful because of the high salinity that blocks the drippers, and producers do not have the financial resources for the maintenance and cleaning of the irrigation system. A study demonstrated that drip irrigation reduces losses by direct evaporation, runoff, and deep percolation due to its high-efficiency potential to improve water use efficiency in the Tafilalet region, where water is a limiting source (Bourziza *et al.*, 2017).

Table 3. Irrigation methods in the oasis

Irrigation method	Frequency (n)	Percentage
Submission irrigation	37	66
Drip irrigation	11	20
Two methods	8	14

Explanations: n = number of occurrences.

Source: own study.

DATE PALM PRODUCTION SYSTEM

Density and date palm cultivars

An overall of 25,414 date palm trees have been cultivated in the study area. A great part of the trees were 'Majhoul' and 'Khalts' cultivars, respectively, with a percentage of 41% and 23%. The remaining cultivars were 'Boufeggous' (18%), 'Bouslikhane' (14%), 'Bouzekri' (2%), and 'Najda' (2%) cultivars (Fig. 3).

Table 4 below shows that most of the date palms cultivated, over 57% of the total date palm trees planted, were productive (14,484). Each producer holds an average of 259 palms.

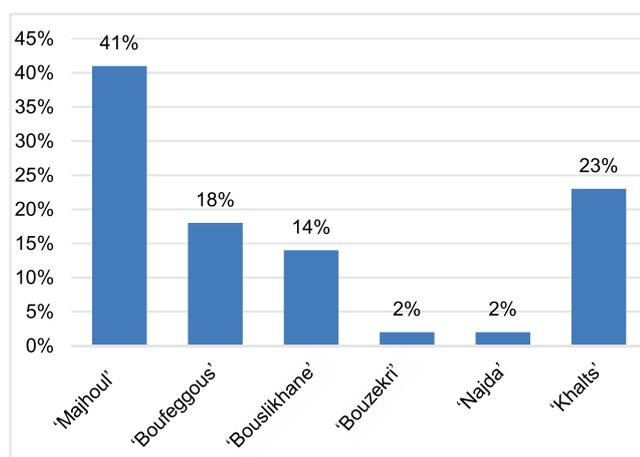


Fig. 3. Date palm cultivar profile in the study area, source: own study

Table 4. Number of cultivated palm trees and production density

Variable	Unit	Amount
Total number of trees cultivated	pcs	25,414
Number of productive trees (≥ 5 years old)	pcs	14,484
Productive trees	%	57
Average number of trees per producer	pcs-producer ⁻¹	259
CV (average tree)	%	98
Average density	pcs-ha ⁻¹	98
CV (average density)	%	61

Explanations: CV = coefficient of variation.

Source: own study.

In addition, the presence of 43% of non-productive palm shows that production will increase significantly in the coming years. In particular, 'Majhoul' is considered very valuable and is, at present, the most planted in Morocco, due to the high cost of its fruits. 'Majhoul' and 'Boufeggous' are cultivated mainly as cash crops and plantations or single trees are usually well-managed and constantly renovated (Garbati Pegna *et al.*, 2017a). The same authors claimed that 'Khalis' is characterised by extremely variable characteristics, yield, and quality. They are not much requested in the market, though often their abundance compensates for low prices, so they are never present in new plantations. They provide, however, a good integration in animals' alimentation, and from an ecological and long-term perspective. They are essential because of their diversity that constitutes an important genetic reserve. For these reasons, preserving the ancient oases not only holds economic and cultural significance but also carries strategic importance.

Tillage and weeding

The application of soil tillage and weeding are crucial operations for date palm trees. They contribute to overall health, productivity and improve fruit quality. During the period from January to March, producers engage in basic manual labour around the palm trunk using small tools such as pickaxes and shovels. This labour is typically done to prepare the soil for organic fertilisers or when establishing water canals known as "saquias" to irrigate the cultivated crops.

However, weeding is carried out infrequently, despite its significance in removing competing weeds and parasitic plants that hinder the growth of date palms and the development of high-quality fruits.

Irrigation

Water is essential for the good growth of date palm trees. The underground water source is the primordial irrigation source for 74% of producers, wells and "khattara" are used, respectively, by 61 and 13% of them. Just 5% of producers irrigate using water dams (superficial water), and 18% use both superficial, water flooding (which can occur whenever rainfall exceeds the ground surface capacity to absorb the water) and underground water "khattara". The irrigation from "khattara" was conducted following the turn system. In oases, most of the water for crops comes from natural groundwater, and in some coastal areas rising tides push water into date palm plantations (Carr, 2013). The Tafilalet water table is attributed to the efforts of producers who, for centuries, have created an underground reservoir through their irrigation practices, primarily reliant on the dispersion of floodwaters, without relying on external sources of water (Margat and Moullard, 1957; El Khoumsi *et al.*, 2014).

The determination of water quantity applied in the studied oasis is almost difficult since most of the producers use the submersion method to irrigate their date palm trees. Indeed, Sedra (2012) highlights that in the case of Moroccan climatic conditions, the annual water requirement depends on salinity and soil type and can switch between 15 thousand and 20 thousand $\text{m}^3 \cdot \text{ha}^{-1}$ by submersion system, but these needs can be reduced to about 40% in the case of drip irrigation systems. Sabri *et al.* (2017) claimed that in the case of the Tafilalet region, Errachidia with an average annual requirement of the order of 7,870 $\text{m}^3 \cdot \text{ha}^{-1}$. The yearly water needs for date palm trees range from 15 thousand to 55 thousand $\text{m}^3 \cdot \text{ha}^{-1}$, mainly influenced by factors such as the location, level of irrigation management, and irrigation quality (Alazba, 2004). The quantity of water required depends on climate conditions, soil water-holding capacity, the age of the date palm, and the irrigation system. In fact, producers irrigate their palm trees using submersion irrigation 3 to 7 times per month and with drip irrigation 4 to 9 times per month.

Fertilisation

Based on observation and data analysis, producers use both organic and mineral fertilisers to supply nutrients to the date palm trees. At the beginning of the winter, during vegetative rest, producers incorporated organic fertiliser "manure" around the trunk of date palm trees. They applied an average quantity of 51 $\text{kg} \cdot \text{palm}^{-1}$ (Tab. 5), generally every two years. Organic manure provides the essential element for the palm, helps maintain soil fertility, and supports the healthy growth of the palms.

The combination of organic and mineral fertilisers can improve crop growth and yield in the short term (Kassem and Marzouk, 2010). Producers broadcast mineral fertilisers to complete the date palm's nutritional needs. The date palm benefits indirectly from the application of chemical fertilisers applied for the intercropping planted. Three types of chemical fertiliser products are used: urea (33.5%), superphosphate (18–46–00), and NPK (14, 28, 14), with an average amount of 0.8 kg N, 1 kg P_2O_5 , 0.3 kg K_2O applied yearly per palm (Tab. 5). The frequency of mineral fertiliser intake can range from two to

Table 5. Quantities of organic and mineral fertilisers applied yearly in the study area

Fertiliser type	Average amount	Maximum	Minimum	CV (%)
Organic fertiliser (manure) (kg.palm ⁻¹ .y ⁻¹)	51	150	4	64
Nitrogen (N) (kg.palm ⁻¹)	0.8	3.1	0.2	76
Phosphate (P ₂ O ₅) (kg.palm ⁻¹)	1.0	2.8	0.2	60
Potassium (K ₂ O) (kg.palm ⁻¹)	0.3	0.6	0.1	53

Explanations: CV = coefficient of variation.

Source: own study.

four times per year, during vegetation rest (mixed with manure), after pollination, and during fruit set.

The operation of fertilisation is essential to improve date palm production and productivity. Producers tend to use a lower quantity of manure and mineral fertilisers than what researchers recommend. Sedra (2012) recommended a yearly application of an amount of 150 kg.palm⁻¹ of organic fertiliser, and 2.5 kg N, 2.5 kg P₂O₅, 5 kg K₂O per palm, due to the low organic matter content of the soil. Awad *et al.* (2006) claimed that the application of 50 kg of organic manure with 1.2 kg N, 0.6 kg P, 1.2 kg K per palm tree could increase the yield and double it. Elsadig *et al.* (2017) found that a quantity comprised of 0.6 kg N, 1.2 kg P₂O₅, 0.7 kg K₂O per palm yearly applied, and mixed with 100 g of microelements recorded the highest values in the fruit weight and fruit dimensions (length, diameter, and volume).

In the study area, producers believe that date palms can yield dates even without the application of fertilisers or minimal incorporation of such substances. The same observation is made by Al-Qurashi, Awad and Ismail (2015), adding that small producers mistakenly thought that fertilisation of date palm trees was not essential since they can grow and produce dates under all types of soils and even in the harsh climate of oases. Date palm trees require specific attention in the application of fertilisers since it is a crucial operation to enhance the quantity and quality of dates production. It is known that it depends on several variables, essentially soil type. Producers have to analyse soils to determine exactly the correct quantity to apply. Because of the limited access to information and technical guidance regarding the appropriate fertiliser quantities, the elevated costs of fertiliser products affect their enthusiasm to explore methods to enhance date palm productivity. Consequently, producers opt to utilise the available fertilisers for all crops cultivated on their oasis farm.

Pollination practices

Date palm trees are one of the dioecious species. Pollination by wind, bees, and insects is possible, but the fruit set by such a method is minimal and thus the expected yield is relatively low, the fruits have no commercial value. Producers in the study area rarely conduct this method, they carried out a traditional method by placing at least 2–3 male spikelets in a female spathe by using their pollen or those of their neighbours in case of insufficiency. Pollination is done in the morning between 10 am and 12 pm, in the spring season (March–April). It is done over several days since the female spathe does not open all at once. Benziouche and

Chehat (2010) highlighted the requirement of the pollination operation, particularly in terms of choice of pollen, as well as the choice of opportune moments where the climatic conditions are favourable for its success to increase the rate of fruit set. Producers surveyed found themselves with unfertilised trees, this is due either to the lack of mastery of the pollination technique by the workforce and/or the wrong choice of the timing of the application and/or the choice of pollen that does not have a large biological capacity. Sedra (2012) emphasised three key conditions for successful pollination: selecting a male with significant traits, especially high pollen grain production, understanding the floral receptivity period of female flowers for fertilisation, and possessing expertise in various pollination methods. If this process is poorly executed, the producer may experience a deficit in the yield of a certain number of kilograms of dates.

Fronds pruning

From November to January, after harvesting, all date palm producers used to remove the palm dry leaves and leaf bases. Some of them, eliminated date spines, fibre, and high offshoots to facilitate pollination practice. The palms eliminated are used to carry heavy fruit bunches to avoid them being damaged.

Removal of spines is called dethroning. With a pruning knife, date spines are usually removed from the new growth of fronds in the crown of the palm just before the pollination season to allow easy access to the date spathes as they bloom. Such an operation will ensure a safe approach to the spathes for their pollination and also avoid any risk of injury to labourers during other technical practices, as tying fruit bunches down, covering bunches, and harvesting (Abul-Soad, Mahdi and Markhand, 2015).

Date fruit management

Three types of date fruit management are advised to be conducted in order to produce quality date fruits. Tying, thinning, and limiting are conducted for cultivars of high add value ('Majhoul', 'Boufeggous', and sometimes good quality 'Khalts'). Tying consists of leaning the regimes between the palms to endure good exposure of dates to the sun and avoid the dates injuring by palms' spines. Proper tying reduces the breakage of fruit bunches, it is the organisation of bunches in the tree space to enable the most convenient management during bag coverage and harvest (Cohen and Glasner, 2015). Thinning and limiting are operations that consist of reducing the number and/or length of spikelets to promote the development of fruit, improve its quality (size), and reduce the relative humidity of the air which is often harmful and causes rot and mould in dates (Sedra, 2012).

Every two years, without human intervention, the date palm bears many fruits. The following year, the harvest will be less, so it is necessary to do fruit thinning to provide more consistency in the production, enhance the size, and improve the quality of dates (Bouguedoura *et al.*, 2015). Producers used to conduct these operations for some time to save time and money, which induced wrinkled and withered fruits with low market value. Date bunch covering is another interesting operation that protects date fruits in the ripening period from hard climate conditions and pests. Bunch covering is not only practised against rain damage but is traditionally also used to protect maturing fruit from birds, late-season pests, and prevent early-ripening fruit from falling to the ground. A bunch cover may capture heat inside the covers, which

accelerates the fruit ripening (Abul-Soad, Mahdi and Markhand, 2015). This operation was employed by 56% of the producers surveyed and for 'Majhoul' and 'Boufeggous'; the remaining producers claimed that the price of the bunch cover operation is costly for them.

Plant protection

Pests and diseases are the main constraints affecting productivity and damage the quality of dates. In the study area, the phytosanitary situation is a cause for concern, as a significant number of pests and diseases have been detected in the surveyed farms. Notably, white cochineal scale (*Parlatoria blanchardii* Targ), red palm mites (*Raoiella indica*), inflorescence rot Khamedj, and bayoud were observed, with infection rates of 77, 46, 48, and 45% respectively. In addition to these, pests (rats, ants, and spiders) and heart rot with 5 and 3%, respectively, were observed (Tab. 6).

Table 6. The diseases and pests of the farms surveyed

Harmful factor	Name	Causal agent	Percentage
Disease	vascular fusariosis (bayoud)	<i>Fusarium oxysporum</i> f. sp. <i>albedinis</i>	45
	inflorescences rot (Khamedj)	<i>Mauginiella scaetiae</i>	48
	heart rot	<i>Thielaviopsis paradoxa</i>	3
Pest	white cochineal scale (<i>Parlatoria blanchardii</i> Targ)	–	77
	red palm mites (<i>Raoiella indica</i>)	–	5
	other insects	–	46

Source: own study.

Even in this situation, producers in the study area do not make protection a priority. The majority of the producers (57% of them) do not apply any protection or treatment to control the propagation of pests and diseases. The remaining producers (43%) used pesticides to control white cochineal scale and inflorescences rot diseases, and traditional treatments (municipal soap, stone, etc.) against rats, ants, and spiders. Even so, they complained that pests and/or pathogens persist in their palms. Pests and diseases negatively affect date production and inhibit the good development of date palm trees. Dates yield fluctuates every year due to pests and pathogens (Acherkouk, *et al.*, 2003). In the case of the study region, there is no study to describe the phytosanitary situation, except that Acherkouk, *et al.* (2003) noted that bayoud disease deteriorates every year in 2 to 4% of Morocco's oases. It is clear that there is a lack of technical control or that the products used are unsuitable for pests and diseases. Therefore, the accumulation of the palm's dry leaves and leaf bases, which results from thinning, in the trunk of the palm trees and even the non-application of palm management is some of the causes of pest and disease propagation, which is accelerated by the climate change and the non-reasonable use of phytosanitary products. The lack of curative means, the chemical control of

dates which is rarely carried out or is done irregularly, the lack of extension and accompaniment, and the unavailability of phytosanitary products and their high price, are the main causes for the lack of effective prevention control.

Harvest

Producers harvest their dates in the "Tamar stage" when they are dark brown. From October to December, and depending on the type of date cultivar, producers climbed to the top of palm trees several times a week to remove dates from bunches. To climb the height of palm trees, they employ the simplest means like wooden ladders and strong ropes. After harvest, rigorous filtering and sorting of dates were conducted to select the first, second, and third dates' quality. The remaining dates are destined for livestock's alimentation. The date harvesting methods depend on the type of cultivar. 'Majhoul' and 'Boufeggous' cultivars are harvested by cutting just the mature fruit, and the other cultivars are harvested by cutting the bunch at once and leading them dry under the sun.

The average annual production in the study area amounted to 47 kg-palm⁻¹. The quantity harvested per tree varied significantly based on the cultivar (Fig. 4). Notably, 'Bouslikhane', 'Bouzekri', 'Khalts', and 'Najda' cultivars exhibited the highest yields, with 76, 62, 59, and 47 kg-palm⁻¹, respectively. In contrast, the 'Majhoul' and 'Boufeggous' cultivars had comparatively lower yields, with only 28 and 37 kg-palm⁻¹, respectively. The differentiation of yield produced between the cultivars is mainly due to the morphological difference and specificity of each cultivar and to the cultural practices of each producer. Therefore, the traditional harvesting method requires a large workforce. The picking of one tree requires the mobilisation of at least two workers. In particular, these methods result in a high rate of losses due to the drying out of bunches, which already contain contaminated, uncollected dates, especially in the oases that are not clean.

The study's analysis shows a higher yield than that reported by the Regional Agricultural Development Office (Fr.: ORMVA-TF – Office Régional de Mise en Valeur Agricole du Tafilalet) (ORMVA-TF, 2016) in the Tafilalet region in 2016, which was 30.5 kg-palm⁻¹, and higher than the national average, which typically is between 20 and 25 kg-palm⁻¹ (Darif, 2014). This indicates the considerable attention given to the sector by the Moroccan Government, with its development expected to have a notable socio-economic impact on oasis areas. The average date yield observed closely approaches the declared average in Tunisia

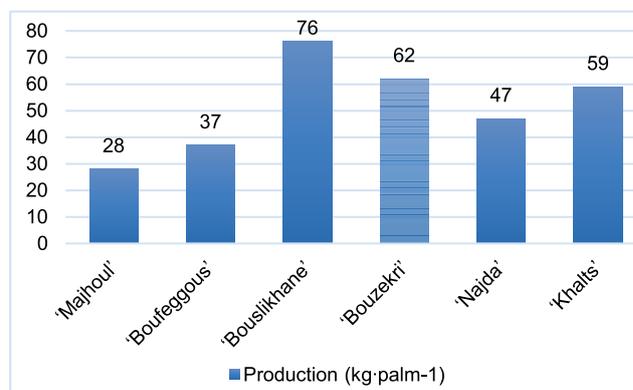


Fig. 4. Annual quantity of dates produced in the study area for the 2016-2015 season; source: own study

oases, which is approximately 38 kg-palm⁻¹ (Belloumi and Matoussi, 2006). However, this figure contrasts significantly with that of Middle Eastern countries like Egypt, where it reaches about 102 kg-palm⁻¹ (Bekheet and El-Sharabasy, 2015), or Saudi Arabia, where it falls between 60 and 70 kg-palm⁻¹ (Aleid, Al-Khayri, and Al-Bahrany, 2015). To improve date palm production in the oases, Moroccan new agricultural strategy, Green Generation 2020–2023, aims to plant 4 mln palms on 42 thous. ha, i.e., 2.6 mln palms by restoring existing oases and 1.4 mln palms in new plantations in the extension (MAPMDREF, 2022).

MARKETING

Producers surveyed produced about 929.6 Mg of dates. Direct marketing is the most common marketing channel used in the study area. A lot of the total dates produced (95%) are destined for the Moroccan market, of which 53% are sold to collectors (intermediaries), sold after harvest (52%) and sold before harvest (1%), 41% in the market “Souk”, and 1% is stored. Even so, the quantity of self-consuming and destined for livestock alimentation (diets) is low, with 3 and 2%, respectively (Tab. 7). Date marketing in the study area is very modest and leads to the intermediaries (collectors) controlling the local market and leaving producers little profitability, even though they are the principal producers of dates. They find many constraints in the commercialisation of their dates, such as the isolation of farms and the weak logistical means in addition to the little information and the financial means to ensure correct marketing. These constraints in addition to the insufficiency of industrial valorisation are the main downstream issues (Harrak and Chetto, 2001). The same authors resumed that the Moroccan dates’ marketing circuit is poorly organised.

CONCLUSIONS

The date palm, a symbol of fertility and sustainability, has garnered international acclaim, yet faces regression worldwide due to a slew of environmental, technical, and socio-economic challenges. Our study sheds light on the specific hurdles facing date palm production in Tafilalet oases. Our findings reveal a pressing issue, the disconnection between traditional practices and production standards. Here, the limited opportunities offered to young, educated producers loom large as a significant obstacle. Their potential to embrace innovative technologies and drive the sector’s evolution remains largely untapped, and the allure of alternative income-generating activities threatens the modernisation of family farms. Another concern lies in the fragmentation of farms, a consequence of the inheritance system, which impedes the expansion of palm groves. Furthermore, the dearth of initiatives aimed at revitalising irrigation systems, coupled with a deficit in technological knowledge regarding date palm cultivation, presents a big challenge. The shortage of training programs and access to credit facilities further compounds the struggle. The culmination of these issues has pushed some producers to make the painful decision to abandon their oases, echoing the broader regression observed in date palm farming. However, in this sombre reality, a glimmer of hope remains. By addressing these constraints head-on, offering support to young, educated producers, and fostering a culture of innovation and sustainability, we can rekindle the glory of our date palm sector.

As we conclude this study, we advocate for a renewed commitment to the preservation and modernisation of palm groves. Let us draw inspiration from our heritage while embracing the potential of modern practices, nurturing our oases, and securing a thriving future for this symbol of fertility

Table 7. The category of destination for dates produced by the producers interviewed in the season 2016/2017

Specification	Consumed	Livestock feeds	Marketing operation				Total
			stored	Market “Souk”	collectors		
					sold after harvest	sold before harvest	
Quantity (Mg.y ⁻¹)	27.8	18.6	9.3	381	483.4	9.3	929.6
Percentage	3	2	1	41	52	1	100

Source: own study.

Morocco is considered one of the greatest date consumers in the world. However, the quantity produced is far away from satisfying the local needs. Following the statistics of the Administration des Douanes et Impots Indirects (no date), Morocco imports have grown by 68%, reaching 69 Gg in 2016; this growth is attributed to high domestic demand for dates; consumption reaches 3 kg per person at the national level and increases to 15 kg per person in production areas. The principal importation sources are from Tunisia, Egypt, and the UAE (Administration des Douanes et Impots Indirects, no date). In addition to that, producers tried to sell their production directly after harvest, because they were afraid to lose their production since the storage system was inadequate with the date’s refrigeration norms.

and sustainability. In our collective efforts, we can ensure that the date palm’s renowned reputation continues to shine brightly on the international and national stages.

CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

ACKNOWLEDGEMENTS

We would like to thank all the actors for their participation and support of time.

FUNDING

This work was supported by the R4D project “Application of organic bio-fertilizer technology to improve the sustainability of date palm production and cultivation” with the grand number IZ07Z0_160904 funded by the R4D program, the Swiss Program for Research on Global Issues for Development, a partnership of the Swiss Agency for Development and Cooperation and the Swiss National Science Foundation.

REFERENCES

- Abul-Soad, A.A., Mahdi, S.M. and Markhand, G.S. (2015) “Date palm status and perspective in Pakistan,” in J.M. Al-Khayri, S.M. Jain, D.V. Johnson (eds.) *Date palm genetic resources and utilization. Volume 2: Asia and Europe*. Dordrecht: Springer, pp. 153–205. Available at: https://doi.org/10.1007/978-94-017-9707-8_5.
- Acherkouk, M. et al. (2003) “Système de production oasiens et sylvo-pastoraux: Interaction, complémentarité et développement durable. Cas du bassin de Ghéris (Maroc) [Oasis and agro-sylvo-pastoral production system: Interactions, complementarity, and sustainable development. Case of the Ghéris basin (Morocco)],” *Série de Documents de Travail*, 113. Rabat: Institut National de la Recherche Agronomique, Centre International pour la Recherche Agricole orientée vers le développement, Office Régional de Mise en Valeur Agricole du Tafilalet.
- Administration des Douanes et Impôts Indirects (no date) *Statistiques des importations et exportations dattiers [Statistics on imports and exports of dates]*. Available at: <https://www.douane.gov.ma/web/guest> (Accessed: March 04, 2017).
- Ait Hmida, A. (2003) “Systemes de production et strategies des agriculteurs dans les oasis de la region d’Errachidia au Maroc [Production systems and strategies of farmers in the oases of the Errachidia region in Morocco],” *New Medit*, 2, pp. 37–43. Available at: https://newmedit.iamb.it/share/img_new_medit_articoli/170_37aithmida.pdf (Accessed: March 27, 2020).
- Al-Qurashi, A.D., Awad, M.A. and Ismail, S.M. (2015) “Growth, yield, fruit quality and nutrient uptake of tissue culture-regenerated ‘Barhee’ date palms grown in a newly established orchard as affected by NPK fertigation,” *Scientia Horticulturae*, 184, pp. 114–122. Available at: <https://doi.org/10.1016/j.scienta.2014.12.034>.
- Alazba, A. (2004) “Estimating palm water requirements using Penman-Monteith mathematical model,” *Journal of King Saud University*, 16(2), pp. 137–152.
- Aleid, S.M., Al-Khayri, J.M. and Al-Bahrany, A.M. (2015) “Date palm status and perspective in Saudi Arabia,” in J.M. Al-Khayri, S.M. Jain, D.V. Johnson (eds.) *Date palm genetic resources and utilization. Volume 2: Asia and Europe*. Dordrecht: Springer, pp. 49–95. Available at: https://doi.org/10.1007/978-94-017-9707-8_3.
- ArcGIS software (no date) *Map of some municipalities in Tafilalet region*. Esri.
- Awad, M.A. et al. (2006) “Effect of elemental sulfur, chemical and organic fertilizers on nutrient uptake, yield and fruit quality of date palm trees (*Phoenix dactylifera* L.) c.v. ‘Neghal’,” *Seventh Annual U.A.E. University Research Conference, College of Food and Agriculture*, pp. 34–39.
- Bekheet, S.A. and El-Sharabasy, S.F. (2015) “Date palm status and perspective in Egypt,” in J.M. Al-Khayri, S.M. Jain, D.V. Johnson (eds.) *Date palm genetic resources and utilization. Volume 1: Africa and the Americas*. Dordrecht: Springer, pp. 75–123. Available at: https://doi.org/10.1007/978-94-017-9694-1_3.
- Belarbi, A. et al. (2004) “Agrobiodiversité et durabilité des systèmes de production oasiens dans la palmeraie d’Aoufouss Errachidia – Maroc [Agrobiodiversity and sustainability of oasis production systems in the Aoufouss Errachidia palm grove – Morocco],” *Série de Documents de Travail*, 121. Rabat: Centre International pour la Recherche Agricole orientée vers le développement, Institut National de la Recherche Agronomique C.R.R.A. d’Errachidia, Office Régional de Mise en Valeur Agricole du Tafilalet, International Plant Genetic Resources Institute.
- Belloumi, M. and Matoussi, M.S. (2006) “A stochastic frontier approach for measuring technical efficiencies of date farms in southern Tunisia,” *Agricultural and Resource Economics Review*, 35(2), pp. 285–298. Available at: <https://doi.org/10.1017/s1068280500006730>.
- Benziouche, S.E. and Chehat, F. (2010) “La conduite du palmier dattier dans les palmeraies des Zibans (Algérie) Quelques éléments d’analyse [The management of date palms in the palm groves of the Zibans (Algeria) Some elements of analysis],” *European Journal of Scientific Research*, 42(4), pp. 644–660.
- Botes, A. and Zaid, A. (2002) “The economic importance of date production and international trade,” in A. Zaid, E.J. Arias-Jimenez (eds.) *Date palm cultivation. FAO plant production and protection paper*, 156 rev. 1. Rome: Food and Agriculture Organization. Available at: <https://www.fao.org/3/Y4360E/y4360e07.htm> (Accessed: July 04, 2020).
- Bouguedoura, N. et al. (2015) “Date palm status and perspective in Algeria,” in J.M. Al-Khayri, S.M. Jain, D.V. Johnson (eds.) *Date palm genetic resources and utilization. Volume 1: Africa and the Americas*. Dordrecht: Springer, pp. 125–168. Available at: https://doi.org/10.1007/978-94-017-9694-1_4.
- Bourziza, R. et al. (2017) “Modélisation de l’irrigation en goutte à goutte enterré du palmier dattier sous les conditions oasiennes [Modeling underground drip irrigation of date palms under oasis conditions],” *Cahiers Agricultures*, 26(3), 35007. Available at: <https://doi.org/10.1051/cagri/2017023>.
- Carr, M.K.V. (2013) “The water relations and irrigation requirements of the date palm (*Phoenix dactylifera* L.): A review,” *Experimental Agriculture*, 49(1), pp. 91–113. Available at: <https://doi.org/10.1017/s0014479712000993>.
- Chandrasekaran, M. and Bahkali, A.H. (2013) “Valorization of date palm (*Phoenix dactylifera*) fruit processing by-products and wastes using bioprocess technology – Review,” *Saudi Journal of Biological Sciences*, 20(2), pp. 105–120. Available at: <https://doi.org/10.1016/j.sjbs.2012.12.004>.
- Chelleri, L. et al. (2014) “Responses to drought and desertification in the Moroccan Drâa Valley region: resilience at the expense of sustainability?,” *The International Journal of Climate Change: Impacts and Responses*, 5(2), pp. 17–33. Available at: <https://doi.org/10.18848/1835-7156/cgp/v05i02/37199>.
- Cohen, Y. and Glasner, B. (2015) “Date palm status and perspective in Israel,” in J.M. Al-Khayri, S.M. Jain, D.V. Johnson (eds.) *Date palm genetic resources and utilization. Volume 2: Asia and Europe*. Dordrecht: Springer, pp. 265–298. Available at: https://doi.org/10.1007/978-94-017-9707-8_8.
- Darif, N. (2014) *Palmier dattier: la Caravane OCP oeuvre pour un meilleur rendement [Date palms: the OCP Caravan works to improve yields]*. La Vie Éco. Available at: <https://www.lavieeco.com/affaires/palmier-dattier-la-caravane-ocp-oeuvre-pour-un-meilleur-rendement-29839/> (Accessed: January 27, 2021).
- Ekwke, C., Nwachukwui, C. and Ironkwea, G. (2009) “Appraisal of the use of mechanized cassava grate ramon farm households in south

- eastern Nigeria,” *Nigerian Journal of Rural Sociology*, 9(1), pp. 17–24.
- El Khoumsi, W. *et al.* (2014) “Deterioration of groundwater in arid environments: What impact in oasis dynamics? Case study of Tafilalet, Morocco,” *International Journal of Environmental and Ecological Engineering*, 8(11), pp. 764–770.
- El Khoumsi, W. *et al.* (2017) “La durabilité du système oasien face à la détérioration des ressources en eaux souterraines: Cas de la palmeraie de Tafilalet [The sustainability of the oasis system in the face of deteriorating groundwater resources: The case of the Tafilalet palm grove],” *Revue Marocaine des Sciences Agronomiques et Vétérinaires*, 5(1), pp. 41–51.
- El-Juhany, L.I. (2010) “Degradation of date palm trees and date production in Arab countries: Causes and potential rehabilitation,” *Australian Journal of Basic and Applied Sciences*, 4(8), pp. 3998–4010.
- Elsadig, E.H. *et al.* (2017) “Impact of organic manure and combination of N P K S, on yield, fruit quality and fruit mineral content of Khenazi date palm (*Phoenix dactylifera* L.) cultivar,” *Journal of Scientific Agriculture*, 1, pp. 335–346. Available at: <https://doi.org/10.25081/jsa.2017.v1.848>.
- Essarioui, A. and Sedra, M.H. (2017) “Lutte contre la maladie du bayoud par solarisation et fumigation du sol : Une expérimentation dans les palmeraies du Maroc [Control of bayoud disease by solarization and soil fumigation: Experimentation in Moroccan palm groves],” *Cahiers Agricultures*, 26(4), 45010. Available at: <https://doi.org/10.1051/cagri/2017043>.
- FAO (2014) *Crops and livestock products*. FAOSTAT. Available at: <https://www.fao.org/faostat/en/#data/QCL> (Accessed: March 01, 2017).
- Garbati Pegna, F. *et al.* (2017a) “Improving the date production chain in the Moroccan oases through small mechanization inputs to support the governmental development strategies” in *Tropentag 2017. Conference on International Research on Food Security, Natural Resource Management and Rural Development*, Bonn, Germany 20–22 Sep 2017. Bonn: University of Bonn. Available at: <https://repo.mel.cgiar.org/handle/20.500.11766/7483> (Accessed: March 30, 2021).
- Garbati Pegna, F. *et al.* (2017b) “Sustaining Moroccan oasis agricultural system through small mechanization inputs” in *CUCS Milano 2017 Migration. Peace and development. New challenges and new faces for Cooperation. V CONGRESS of the Italian University Network for Development Cooperation*, Milan, Italy 14–15 Sep 2017. Milan: Italian University Network for Development Cooperation. Available at: <https://repo.mel.cgiar.org/handle/20.500.11766/7375> (Accessed: September 28, 2020).
- Harrak, H. and Chetto, A. (2001) *Valorisation et Commercialisation des dattes au Maroc [Valorization and marketing of moroccan dates]*. Edition INRA 2001. Marrakech: Imprimerie Al Watania, Royaume du Maroc Institut National de la Recherche Agronomique, Office Allemand de la Cooperation Technique.
- HCP (2011) *Chapitre VII Evolution du secteur agricole et perspectives de développement rural. Dynamique urbaine et développement rural au Maroc, Direction Régionale Marrakech-Safi, Direction Provinciale De Safi [Chapter VII : Evolution of the agricultural sector and perspectives on rural development, Direction Régionale Marrakech-Safi, Direction Provinciale De Safi]*. Available at: https://www.hcp.ma/region-drda/Dynamique-urbaine-et-developpement-rural-au-Maroc_a55.html (Accessed: June 07, 2021).
- Hussain, N.H.M. (2010) *Global date palm development plan: Global, regional and country level strategies for date palm development keeping in view past and present scenarios as well as expected climatic changes*. Especially formulated for Khalifa International Date Palm Award UAE, Third session. Doha: Soil Research Section, Department of Agricultural Affairs, Ministry of Environment.
- Kassem, H.A. and Marzouk, H.A. (2010) “Effect of different organic fertilizer sources on improving fruit nutritional value and yield of ‘Zaghloul’ dates,” *ISHS Acta Horticulturae: IV International Date Palm Conference*, 882, pp. 737–744. Available at: <https://doi.org/10.17660/actahortic.2010.882.81>.
- Lemlem, A., Alemayehu, M. and Endris, M. (2018) “Date palm production practices and constraints in the value chain in Afar Regional State, Ethiopia,” *Advances in Agriculture*, 2018, pp. 1–10. Available at: <https://doi.org/10.1155/2018/6469104>.
- MAPMDREF (2015) *Directive stratégiques pour la filière phoenicicole [Strategic directives for the date palm sector]*. Rabat: Ministère de l’agriculture, de la pêche maritime, du développement rural et des eaux et forêts.
- MAPMDREF (2022) *Province Errachidia : Présentation du plan de développement du palmier dattier et lancement et visite de projets de développement agricole dans le cadre de la Génération Green 2020–2030 [Province Errachidia: Presentation of the date palm development plan and launch and visit of agricultural development projects within the framework of Generation Green 2020–2030]*. Ministère de l’agriculture, de la pêche maritime, du développement rural et des eaux et forêts. Available at: <https://www.agriculture.gov.ma/fr/actualites/province-errachidia-presenta-tion-du-plan-de-developpement-du-palmier-dattier-et> (Accessed: November 18, 2022).
- Margat, J. and Moullard, L. (1957) “Le régime d’une nappe phréatique en domaine présaharien (Tafilalet, sud-est Marocain) [Groundwater regime in the pre-Saharan region (Tafilalet, southeastern Morocco)]” in *Congrès géologique international*, pp. 299–315.
- Meddich, A. *et al.* (2018) “Optimizing growth and tolerance of date palm (*Phoenix dactylifera* L.) to drought, salinity, and vascular fusarium-induced wilt (*Fusarium oxysporum*) by application of arbuscular mycorrhizal fungi (AMF),” in B. Giri, R. Prasad, A. Varma (eds.) *Root Biology*. Cham: Springer, pp. 239–258. Available at: https://doi.org/10.1007/978-3-319-75910-4_9.
- ORMVA-TF (2016) *Guide de l’investisseur en agriculture dans le tafilalet [Investor’s guide to agriculture in Tafilalet]*. Al-Rachidia: Office Régional de Mise en Valeur Agricole du Tafilalet.
- Ouabouch, H. (2018) “L’agriculture Oasienne Et Les Défis Des Changements Climatiques: Cas Du Maroc [Oasis agriculture and the challenges of climate change: Case of Morocco],” *IOSR Journal of Agriculture and Veterinary Science*, 11(6), pp. 5–12.
- Rabou, A.F.N.A. and Radwan, E.S. (2017) “The current status of the date palm (*Phoenix dactylifera*) and its uses in the Gaza Strip, Palestine,” *Biodiversitas*, 18(3), pp. 1047–1061. Available at: <https://doi.org/10.13057/biodiv/d180324>.
- Rahim, F., Sadiq, M.S. and Mahmood, Z. (2003) “Role of extension agent in the diffusion of date palm cultivation in the District Pangur (Balochistan),” *Sarhad Journal of Agriculture*, 19(4), pp. 595–602.
- Renévoit, G. *et al.* (2009) “Pratiques d’irrigation du palmier dattier dans les systèmes oasiens du Tafilalet, Maroc [Date palm irrigation practices in the oasis systems of Tafilalet, Morocco]” in A. Bouaziz, R. Choukr-Allah, R. Mrbaat, A. Falisse (eds.) *Symposium international «Agriculture durable en région Méditerranéenne (AGDUMED)»*, pp. 196–211. Rabat, Morocco, 14–16 May 2009. Agadir: IAV Hassan II.

- Saaidi, M. (1992) "Comportement au champ de 32 cultivars de palmier dattier vis-à-vis du bayoud: 25 années d'observations [Field behaviour of 32 date palm cultivars towards bayoud: A 25-year survey]," *Agronomie*, 12, pp. 359–370.
- Sabri, A. *et al.* (2017) "Effet de l'irrigation déficitaire contrôlée sur la croissance et le développement foliaire du palmier dattier (*Phoenix dactylifera* L.) [Effect of regulated deficit irrigation on growth and development of leaf date palm (*Phoenix dactylifera* L.)]," *Cahiers Agricultures*, 26(5), 55005. Available at: <https://doi.org/10.1051/cagri/2017033>.
- Sedra, M.H. (2012) *Guide du phoeniculteur: Mise en place et conduite des vergers phoénacoles [Phoeniculturist's guide: Setting up and managing date palm orchards]*. Rabat: Institut National de la Recherche Agronomique.
- Tengberg, M. (2012) "Beginnings and early history of date palm garden cultivation in the Middle East," *Journal of Arid Environments*, 86, pp. 139–147. Available at: <https://doi.org/10.1016/j.jaridenv.2011.11.022>.
- Zabar, A.F. and Borowy, A. (2012) "Cultivation of date palm in Iraq," *Annales Universitatis Mariae Curie-Sklodowska*, 22(1), pp. 39–54.