doi:10.14720/aas.2023.119.3.12436 Original research article / izvirni znanstveni članek

Study on the evolution of the fruit morphological and physico-chemical parameters of 'Majhoul' date palm during fruit growth

Mohamed ARBA [1, 2], Iliass BERJAOUI [3], Ahmed SABRI [4]

Received February 16, 2023; accepted June 18, 2023.
Delo je prispelo 16. februarja 2023, sprejeto 18. junija 2023

Study on the evolution of the fruit morphological and physico-chemical parameters of 'Majhoul' date palm during fruit growth

Abstract: Date palm is an economically important species in the Middle East and North Africa. In Morocco, date palm is the main crop in the southeastern region, mainly in Draa-Tafilalet area. The 'Majhoul' is ranked among the worldwide best quality dates due to its large size and good texture. This work aimed to study the effect of three phases of flowering (early flowering, seasonal and late) on fruit quality of 'Majhoul' during its development. Experiments were carried out on an adult plantation in a modern palm grove in Tafilalet. Obtained results showed that, except for the chemical parameters of the fruit, there is a significant difference ($p \leq 0.01$) between the three flowering phases for the morphological parameters studied (fruit mass, size, and dimensions) during all the fruit development stages. The early flowering phase yielded fruits with higher parameters than the other flowering phases. The mean fruit size (volume) for all the fruit development stages was 22 cm^3 for the early flowering phase, whereas it was only 12.86 and 10 cm^3, respectively, for the seasonal and late flowering phases. The final fruit size was 19.70, 13.55, and 9.97 cm^3, respectively, for the early, seasonal, and late flowering phases.

Key words: Tafilalet area, date palm 'Majhoul', flowering phase, fruit development, fruit morphological and chemical parameters

Raziskava razvoja morfoloških in biokemičnih parametrov plodov dateljeve palme 'Majhoul' v rastni sezoni

Izvleček: Dateljeva palma je ekonomsko pomembna vrsta v Bližnjem vzhodu in severni Afriki. V Maroku je dateljeva palma glavna kulturna rastlina na jugovzhodnih območjih, v glavnem na območju Draa-Tafilalet. Sorta Majhoul je uvrščena med najboljše na svetu zaradi svoje kakovosti, velikih plodov in njihove dobre teksture. V raziskavi je bil preučevan učinek treh obdobij cvetenja (zgodnje cvetenje, cvetenje v glavni sezoni in pozno cvetenje) na razvoj in kakovost plodov. Poskus je potekal v odraslem nasadu z moderno vzgojno obliko v Tafilaletu. Rezultati so pokazali, da so bile z izjemo kemijskih parametrov plodov, značilne razlike ($p \leq 0{,}01$) med tremi obdobji cvetenja v vseh preučevanih morfoloških parametrih plodov (masa, velikost in dimenzije plodov) v vseh fazah razvoja. Zgodnja faza cvetenja je dala plodove, ki so imeli vrednosti vseh merjenih parametrov večje kot plodovi, nastali iz poznejših cvetenj. Povprečna vrednost velikosti plodov (volumen) nastalih po zgodnejm cvetenju je bila 22 cm^3 med tem, ko sta bili velikosti sezonskih in poznih plodov samo12,86 in 10 cm^3. Končne velikosti plodov so bile 19,70; 13,55 in 9,97 cm^3, za plodove nastale iz zgodnjega, sezonskega in poznega cvetenja.

Ključne besede: območje Tafilalet , dateljeva palma 'Majhoul', faze cvetenja, razvoj plodov, morfološki in kemični parametri plodov

1 Plant ecophysiology and cultures of arid zones laboratory, Hassan II Institute of Agronomy and Veterinary Medicine, Agadir, Morocco
2 Corresponding author, e-mail: arbamohamed@yahoo.fr
3 SYGENTA company (Seed distribution and plant protection), Marrakech, Morocco
4 National Institute of Agricultural Research (INRA), Draa-Tafilalet Agricultural Research Center (CRA), Errachidia, Morocco

1 INTRODUCTION

Date palm (*Phoenix dactylifera* L.) is a perennial monocotyledon plant, which is part of the family of Palmaceae and the genus *Phoenix,* which includes 14 species that are native to tropical and subtropical regions of South Asia or East and North Africa (Dransfield et al., 2008; Shengji et al., 2010). It has been currently grown in the Middle East, North Africa, parts of Central and South America, India, and Pakistan (Al-Shahib & Marshall, 2003) and recently introduced in some African countries such as Namibia. Date palm has been an important fruit species in the Middle Eastern and North African countries for a long time (Marondedze et al., 2014). In Morocco, date palm occupies an area of around 52.000 ha and represents the backbone of agriculture of the Oasian regions, mainly Draa-Tafilalet area, which is the main production area in the country. The genetic diversity of date palm in Morocco consists of more than 223 varieties which are well known and represent 52 % of the total population. The rest (48 %) consists of 'khalts', hybrid seedlings. Traditional commercial varieties of good quality represent only 36 % of the national heritage. They consists of the varieties 'Majhoul', which represents 9 % of the national heritage, 'Bouffegous', which represents 15 %, 'Jihel' 12 % and 'Bouskri' which represents only 0.1 % (ORMVAT, 2015).

Dates fruit are oblong drupes or stone fruits with more or less fleshy and fibrous flesh, which represents 85-90 % of the total fruit mass and contains a single seed (Mansour, 2005; Lobo et al., 2014). They are a fundamental nutrient for the oasis populations. They are an important food source rich in sugars, proteins, dietary fiber, antioxidants, and minerals (magnesium, iron, potassium, etc.) (Amira et al., 2011; Rastegar et al., 2012). With an average annual production of 92976 tons in Morocco, the dates provide an average yearly value of 743.8 million dirhams and contribute 40 to 60 % of the income of the Oasian farms. Dates are the engine of the economy of the producing regions and an important cash source for the farmers of these regions and for the financing of their agricultural activities (ORMVAT, 2015). Dates have reached the international market with famous commercial varieties like 'Bouffegous' and 'Majhoul' (Chafi et al., 2015). Several studies have been conducted on the physico-chemical, biochemical, and biological constituents of date varieties (Hasnaoui et al., 2010; Elguerrouj et al., 2011; Chafi et al., 2015), and their results have classified the dates of the 'Majhoul' among the good quality dates with a large size and high sugar content (more than 70 %) (Acourene et al., 2001).

After the fruit set, there are five development stages in date palm, which are based on changes in fruit size, color, texture, and chemical composition. These development stages are known internationally as ''Hababouk" (immature fruits in the form of peas), ''Kimri" (large and green fruits), ''Khalal" (color stage of the fruit which becomes crisp when eaten), ''Rutab" (fruit ripening stage, soft fruit, and succulent texture) and ''Tamar" (full ripening stage and less humid flesh) (Al-Shahib & Marshall, 2003; Fadel et al., 2006). Marondedze et al. (2014) also reported that fruit development of date palm consists of morphological and physiological changes in the fruit, which occur as biological processes associated with cellular metabolic activities. Fruit growth and development in date palm also leads to morphological, physiological, and biochemical changes after fruit set (Lobo et al., 2013).

Date palm is a species where flowering does not occur simultaneously because the spathe emission is done gradually. Consequently, the flowering and pollination of date palm will also occur progressively over time. The growers in the producing regions distribute the flowering in three phases: an early flowering phase, a seasonal, and a late one. Therefore, fruit quality of these flowering phases have not been studied, and very little research has been carried out. However, in modern date palm groves in date palm growing regions of Morocco, producers of the 'Majhoul' have always used the practice of limiting clusters on clusters that are produced from early and late flowering phases and have always opted to maintain the seasonal flowering regimes in their production system. This research work aimed to study the effect of the three flowering phases on fruit development and quality of 'Majhoul' date palm during fruit growth, by harvesting fruit samples over time.

2 MATERIALS AND METHODS

2.1 THE SITE OF TRIALS

The experiment was set up in a modern date palm grove located in the Goulmima region, Tafilalet area (31°41' N, 4°57' W, and 1028 m elevation), and the trials were carried out on a 13-year-old plantation of 'Majhoul' date palm with an IGP (geographical protection index). The planting density is 7 x 6 m (238 palms per hectare). The irrigation system used on the farm is drip irrigation with two drip ramps per planting row and two drips per palm (one drip per ramp). Plants are irrigated once a week during January and February, twice a week during September, October, November, December, March, and April, three times a week during May, and once a day during June, July, and August.The irrigation dose is 500 l per date palm tree.The fertilization program used on the farm is presented in Table 1.

Table 1: Fertilization program used in the farm of trials on a 13-year old plantation of 'Majhoul' date palm in the Goulmima region, Tafilalet area, Morocco

Intake period	Fertilizer used	Dose provided (kg per ha per month)
December January February	Sulfuric acid	10
	Compost	5000
	Acide Humique	5
March April	Hydrocomplex	50
	Phosphoric Acid	5
May June	Hydrocomplex	50
	Phosphoric Acid	15
	Humic Acid	5
July August	Ammonium Sulphate	20
	Sulfiric Acid	10
	Potassium Sulfate	45

P = date palm tree

The pollinating variety is a 'khalt' which is also 13 years old, and the pollination is carried out manually by placing 5 to 7 spikelets of mature male inflorescence in the middle of the female inflorescence, which is slightly attached with a lace of leaflets to maintain the pollen inside the female inflorescence. The pollination period of each flowering phase of date palm in the farm of trials is presented in Table 2.

2.2 PARAMETERS STUDIED AND MEASURES AND OBSERVATIONS REALIZED

Morphological parameters studied included fruit size (volume), dimensions (length and diameter), and fruit mass. Fruit size is determined with a graduated cylinder of 100, 250 and 1000 ml, fruit dimensions are measured with a caliper and fruit, pulp mass and seed mass are measured with an electronic balance having an accuracy of 0.01 g. Fruit shape and color are determined by visual observation. The percentage of pulp relative to fruit and seed mass is determined according to Acourene et al. (2001):

% pulp = pulp mass/fruit mass x 100
Seed mass = fruit mass - pulp mass

The determination of the fruit dry mass is carried out on fruits; which are devoid of their seeds and dried in the oven at a temperature of 70 °C for 48 hours (Achour et al., 2003).

2.3 CHEMICAL ANALYSIS OF THE FRUITS

Chemical analysis of the fruits was carried out on the pH of the fruit juice and the content of total sugars in the fruits. The juice was extracted from the fruits according to the method of Chafi et al. (2015). The fruits were washed with ordinary water, and their seeds were removed. They were then ground very finely with a mortar, and the resulting crusher was added twice its mass in distilled water. The mixture was centrifuged for 20 minutes in a centrifuge; the supernatant was recovered and then filtered using a vacuum quenching. The filtrate was then adjusted with distilled water to 200 ml, and the resulting solution constituted the raw juice to be analyzed. The pH of the juice was determined using a pH meter, and the content of total sugars in the fruits was determined with a digital refractometer.

2.4 THE EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS OF DATA

Adopted experimental design was a completely random design with a single factor; the flowering phase with three repetitions on five date palm trees, which were randomly selected on the farm and pollinated homo-

Table 2: Pollination period of each one of the three flowering phases (early, seasonal and late flowerings) of 'Majhoul' date palm in the Goulmima region, Tafilalet area, number of clusters used per palm and dates of harvesting fruits for morphological measures and chemical analyzes

		Number of clusters used per palm tree of the study					
Flowering phase	Pollinating period	P1	P2	P3	P4	P5	Dates of harvesting fruits
Early flowering	From 23 to 28 February 2016	2	5	2	2	3	06/02/2016 ; 06/22/2016 ; 07/02/2016 ; 07/13/2016 ; 07/31/2016 ; 08/10/2016 ; 09/03/2016
Seasonal flowering	From 9 to 13 March 2016	3	4	5	3	3	
Late flowering	From 25 to 29 March 2016	3	4	0	4	0	

geneously for each flowering phase. Twenty fruits were randomly chosen per flowering phase and fruit harvesting stage, which coincides with a fruit development stage to make measures and analyses. The fruits were selected at a rate of 3 to 5 fruits per cluster at different heights and orientations of the cluster, and the harvested fruits were deprived of their scars. The aim was to carry out the measures of the morphological parameters and the chemical analysis of the fruits in the laboratory to follow the evolution of these morphological and chemical parameters from fruit set to fruit ripening. Table 2 shows the number of clusters selected per date palm of the study and per flowering phase, the number of fruit samples taken, and the dates of harvesting fruits. Fruit samples collected per fruit development stage and flowering phase were placed in white plastic bags, labeled and placed in an isothermal container, and brought back to the laboratory for analysis.

Statistical analysis of data was performed with the Minitab 16 software, the determination of the mean was made by ANOVA with a single factor, and the comparison of the means was performed with the Tukey test with an error of 5 %.

3 RESULTS AND DISCUSSION

3.1 EVOLUTION OF THE MORPHOLOGICAL PARAMETERS OF THE FRUITS DURING THEIR DEVELOPMENT

3.1.1 Evolution of the fruit size and dimensions

The evolution of fruit size and dimensions (length and diameter) in the three flowering phases (early flowering, seasonal and late) of 'Majhoul' date palm during fruit development in Tafilalet area is presented in Figure 1. It shows that fruit size and dimensions are higher in the early flowering phase than in the other phases. This is because the fruits of the early flowering phase have an 11 to 15 days growth advance compared to fruits of the seasonal flowering phase and 28 to 31 days compared to fruits of the late flowering phase. The mean and final values of the fruit size and dimensions in the three flowering phases and for all the fruit harvesting dates are presented in Table 3, and statistical analysis of data has shown that for these parameters, there is a significant difference ($p \leq 0.001$) between the three flowering phases. Several authors have also reported that the stages of fruit development in date palm lead to physical and physiological changes in the fruit, and modifications in color and texture of the fruit from fruit set to fruit ripening (Al-Shahib & Marshall, 2003; Fadel et al., 2006; Lobo et al., 2014). These morphological and physiological changes in the fruits of date palm provide a promising approach for characterizing their development and quality parameters (Marondedze et al., 2014).

For the sixth (July 31 2016) and seventh (August 10 2016) fruit harvesting dates fruit size is not different between the seasonal and late flowering phases, while it is different between these phases for all the other fruit harvesting dates. This convergence in fruit size between these two flowering phases results in low fruit growth in the seasonal flowering phase and high fruit growth in the late flowering phase (Figure 1a). Whereas the difference in fruit size between the seasonal and late flowering phases during the first six fruit harvesting dates (from

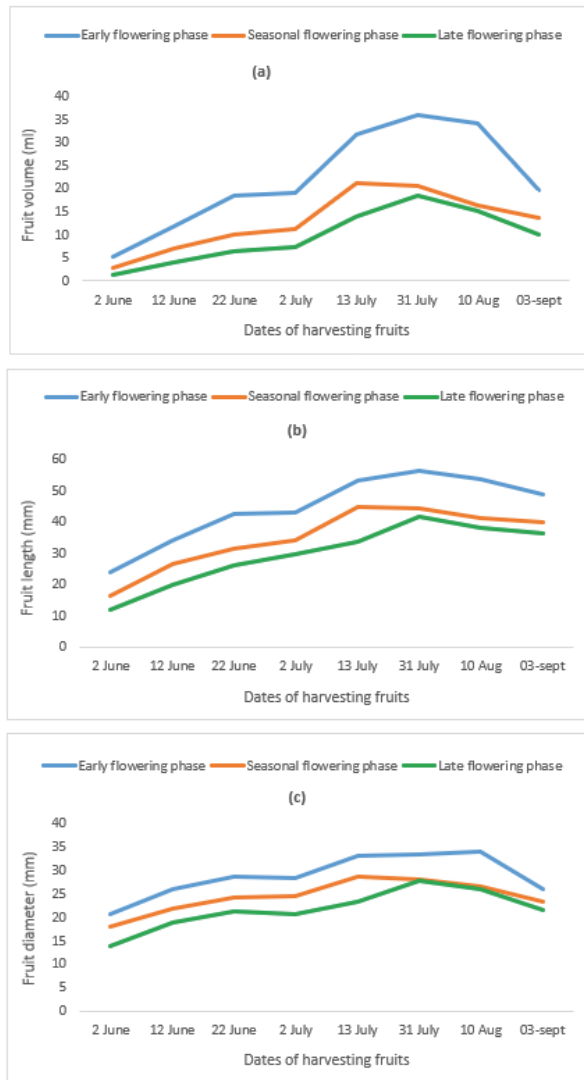

Figure 1: Evolution of the fruit size (volume) (a) and dimensions (b and c) in the early flowering phase, seasonal and late one during fruit growth in 'Majhoul' date palm in the Goulmima region, Tafilalet area, Morocco

Table 3: Mean and final values of fruit size and dimensions in the three flowering phases (early flowering, seasonal and late phases) of 'Majhoul' date palm in the Goulmima region, Tafilalet area.

	Early flowering phase			Seasonal flowering phase			Late flowering phase			
	Fruit length (cm)	Fruit diameter (cm)	Fruit size (cm^3)	Fruit length (cm)	Fruit diameter (cm)	Fruit size (cm^3)	Fruit length (cm)	Fruit diameter (cm)	Fruit size (cm^3)	
Mean value of the fruit parameter for all the fruit harvesting stages	4.43 ± 3	2.87 ± 2	22.02 ± 4	3.47 ± 3	2.43 ± 2	12.86 ± 3	2.95 ± 2	2.15 ± 2	9.55 ± 2.5	**
Final value of the fruit parameter on September 3 2016	48.76 ± 6	26.07 ± 5	19.70 ± 5	39.78 ± 5	23.29 ± 4	13.55 ± 3	36.10 ± 5	21.44 ± 5	9.97 ± 2.5	**

** Significative difference at $p \leq 0.001$

June 2 to July 31 2016) is due to difference in fruit growth between the two flowering phases. Moreover, the difference in the final fruit size between the two flowering phases on September 3 2016 (Figure 1a) is due to the loss of water in the fruits as they are in the ripening phase. Regarding fruit dimensions, fruit length is also the same for the seasonal and late flowering phases at the time of the sixth fruit harvesting stage (Figure 1b), and fruit diameter during the sixth and seventh fruit harvesting stages is also the same for these flowering phases (Figure 1c). This overlap at the time of the sixth fruit harvesting date can be only explained by the difference in fruit growth between these flowering phases, which is due to a delay of about 16 days between the two flowering phases.

3.1.2 Evolution of the fruit, pulp mass and seed mass

Figure 2 presents the evolution of the fruit mass, and pulp mass and seed mass in the three flowering phases during fruit development. It shows that for all the fruit harvesting stages, the mass of fruit, pulp and seed in the early flowering phase is higher than the mass of these elements in seasonal and late flowering phases. This is due to fact that the fruits of the early flowering phase have an 11 to 15 days growth advance compared to the seasonal flowering phase and 28 to 31 days growth advance compared to the late flowering phase. The mean and final values of fresh mass of the fruit, pulp and seed and the mean and final dry mass of the fruit of the three flowering phases for all the fruit harvesting stages are presented in Table 4. Moreover, statistical analysis of data showed that for these parameters of the fruit, there is a significant difference ($p \leq 0.01$) between the fruits of the three flowering phases.

During the sixth (July 31 2016) and seventh (August 10 2016) fruit harvesting dates, the seasonal and late flowering phases yielded fruits with similar fruit and pulp fresh mass, whereas they were different during the other fruit development stages (Figure 2a and b). In the case of seeds, it is only during the last fruit harvesting stage (September 3 2016) that their mass is similar in the three flowering phases. However, it is different between the flowering phases in the other fruit harvesting dates, except for the seventh fruit harvesting date where seed mass of the seasonal flowering phase is close to that of the late flowering phase (Figure 2c). This is due to favorable climatic conditions for fruit development during the early flowering phase, which are favorable to fruit development during the early stages of fruit growth. Some authors have also reported that favorable climatic conditions, which coincide with the early flowering phase, promote the development of growth hormones, mainly

gibberellic acid, which induces the accumulation of reserves in the fruit pulp (El-Otmani et al., 2015). Fruit dry

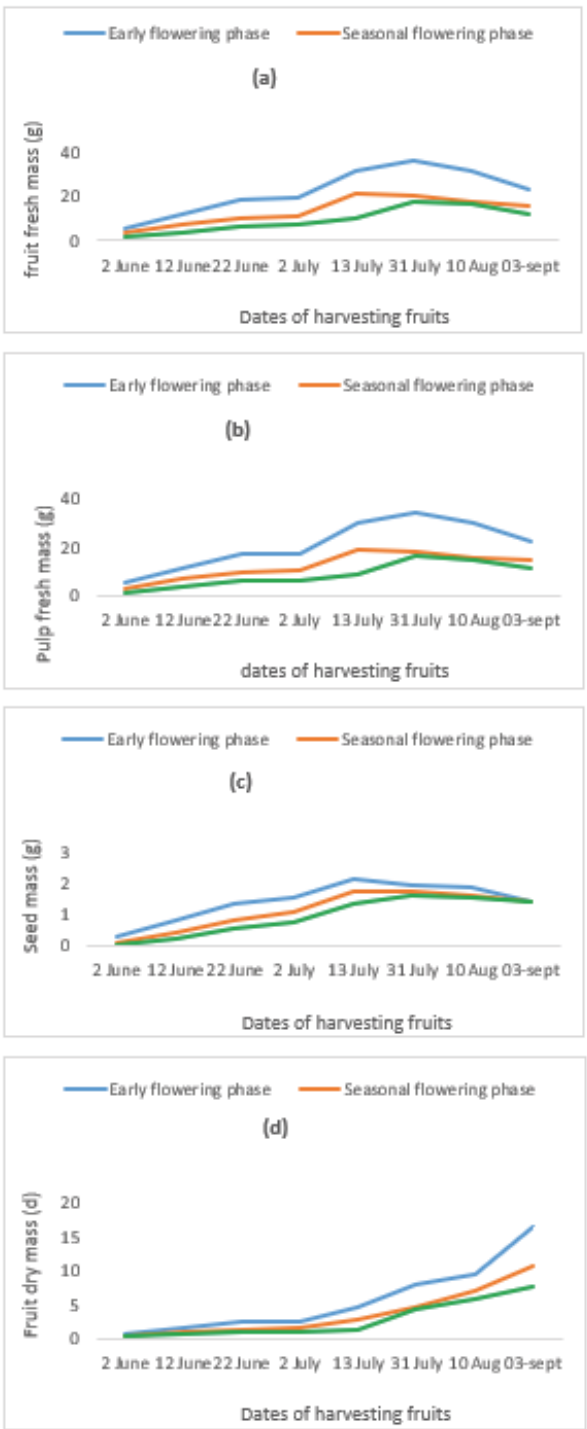

Figure 2: Evolution of the fruit fresh mass (a), pulp fresh mass (b), seed mass (c) and fruit dry mass (d) of the fruits of the early, seasonal and late flowering phases during fruit development of 'Majhoul' date palm in the Goulmima region, Tafilalet area

Table 4: Mean and final values of the fruit and pulp fresh mass, seed mass and fruit dry mass of the fruits of the early, seasonal and late flowering phases of 'Majhoul' date palm in the Goulmima region, Tafilalet area

	Early flowering phase				Seasonal flowering phase				Late flowering phase			
	Fruit fresh mass (g)	Pulp fresh mass (g)	Seed mass (g)	Fruit dry mass (g)	Fruit fresh mass (g)	Pulp fresh mass (g)	Seed mass (g)	Fruit dry mass (g)	Fruit fresh mass (g)	Pulp fresh mass (g)	Seed mass (g)	Fruit dry mass (g)
Mean value of the fruit parameter for all the fruit harvesting stages	22,43 ± 3	20,95 ± 2.5	1,42 ± 1.2	5,73 ± 2.5	13,32 ± 3	12,21 ± 2	1,11 ± 1.2	3,65 ± 2	9,44 ± 2	8,56 ± 1.5	0,91 ± 0.5	2,70 ± 1.4 *
Final value of the fruit parameter on September 3 2016	23.33 ± 3	21.88 ± 2.5	1.42 ± 1.2	16.44 ± 3	16.01 ± 3.5	14.85 ± 2.5	1.40 ± 1.2	10.72 ± 3	12.15 ± 2.5	11.08 ± 2	1.38 ± 1	7.72 ± 2 *

* Significative difference at $p \leq 0.01$

mass is almost similar during the first four harvesting stages in the seasonal and late flowering phases (Figure 2d). This is due to fruit development of these flowering phases, which took the same pace during the early stages of fruit development because the two flowering phases are separated only for a short period.

3.2 EVOLUTION OF THE CHEMICAL COMPOSITION OF THE FRUITS DURING THEIR DEVELOPMENT

The evolution of the chemical composition of the fruits during their development is presented in Figure 3. It shows that the pH of the fruit juice has a similar evolution for the three flowering phases from the second fruit harvesting stage to the last, while it's different between the flowering phases for the first fruit harvesting stage (Figure 3a). The content of total sugars in the fruits also has a similar evolution for the three flowering phases during all the fruit harvesting stages (Figure 3b). The mean and final values of the pH of the fruit juice and the content of total sugars in the fruits of the three flowering phases and for all the fruit harvesting stages are presented in Table 5. Moreover, statistical analysis of data showed that there is no significant difference ($p > 0.05$) between the three flowering phases for the two parameters. This is probably because the flowering phase does not affect the pH of the fruit juice and the content of total sugars in the fruits; however, the fruit harvesting stage affects these parameters in the three flowering phases. Several authors have also reported that the chemical composition of the fruits varies according to the stages of fruit development (Salman Haidar et al., 2013), and fruit development in date palm consists of biological processes which are associated with chemical changes in the cell from fruit set to ripening stage (Lobo et al., 2013; Marondedze et al., 2014).

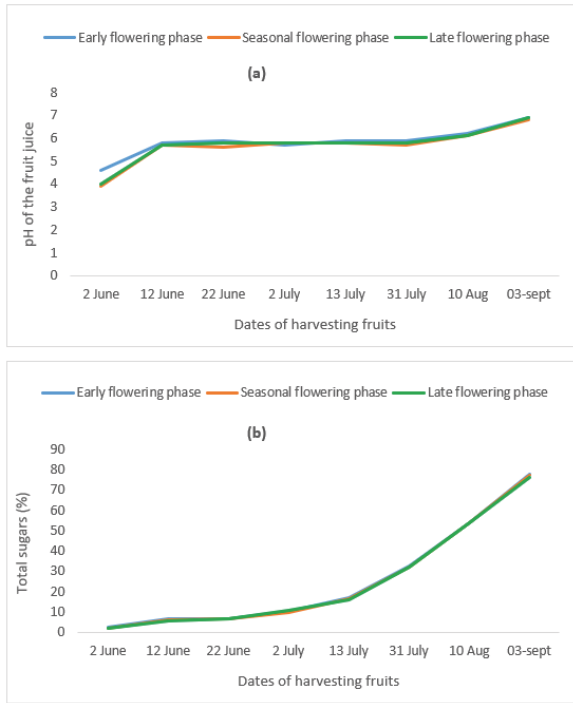

Figure 3: Evolution of the pH of the fruit juice (a) and the content of total sugars in the fruits (b) of the three flowering phases (early flowering, seasonal and late) of 'Majhoul' date palm in the Goulmima region, Tafilalet area

4 CONCLUSIONS

For all studied morphological parameters of the fruit (fruit size and dimensions and fruit mass), there is a difference in their evolution between the three flowering phases during fruit development, and along this evolution, the parameters of the early flowering phase are higher than those of the other flowering phases. This is partly because the fruits of the early flowering phase have

Table 5: Mean and final values of the pH of the fruit juice and the content of total sugars in the fruits of the three flowering phases (early flowering, seasonal and late) of 'Majhoul' date palm in the Goulmima region, Tafilalet area

	Early flowering phase		Seasonal flowering phase		Late flowering phase		
	pH of the fruit juice	Content of total sugars in the fruits (%)	pH of the fruit juice	Content of total sugars in the fruits (%)	pH of the fruit juice	Content of total sugars in the fruits (%)	
Mean value of the fruit chemical parameter for all the fruit harvesting stages	5.86 ± 3	25.89 ± 3	5.68 ± 2.5	25.49 ± 4	5.74 ± 2.5	25.36 ± 4	ns
Final value of the fruit chemical parameter on September 3 2016	6.90 ± 4	77.80 ± 11	6.80 ± 3.5	76.90 ± 11	6.90 ± 4	76.00 ± 11	ns

ns: No significant difference at $p > 0.05$

a remarkable 11 to 31 days of growth advance compared to other flowering phases. On the other hand, favorable climatic conditions for fruit growth (mild temperatures and long days) during the spring season which coincides with the early stages of fruit development of date palm in the region of study. However, for the content of total sugars in the fruits and the pH of the fruit juice, their evolution during the fruit harvesting stages is similar for the three flowering phases, while their values vary from one fruit harvesting stage to another and for the three flowering phases. This is because the flowering phase does not affect these parameters, while the fruit development stage affects these parameters.

Based on these results, we can suggest that growers keep only the early flowering phase clusters for their cluster-limiting operation when the number of clusters of this flowering phase is sufficient. Moreover, when the number of clusters of the early flowering phase is not sufficient, the choice of clusters to be retained in the limitation operation can be made on the clusters of the early and seasonal flowering phases to obtain a good fruit yield and quality and an early entry into production.

5 ACKNOWELGEMENTS

Many thanks to Charouit family in Goulmima. They have made at our disposal their date palm farm for the trials. Many thanks also to the Agricultural Research Center (CRA) of Errachidia and Hassan II Institute of Agronomy and Veterinary Medicine for their support.

6 REFERENCES

Achour, M., Ben Amara, S., Ben Salem, N., Jebali, A., Hamdi, M. (2003). Effet des conditionnements sous vide et sous atmosphère modifiée sur la conservation des dattes DegletNor en Tunisie. *Fruits, 58*(4), 205-212. https://doi.org/10.1051/fruits:2003008

Acourene, S., Buelquedji, M., Tama, M., Taleb, B. (2001). Caractérisation, évaluation de la qualité de la datte et identification des cultivars rares de palmier dattier de la région des Ziban. *Recherche Agronomique, 5(8)*, 19-39.

Al-Shahib, W. & Marshall, R. J. (2003). The fruit of the date palm: Its possible use as the best food for the future. *International Journal of Food Science and Nutrition, 54*, 247-259. https://doi.org/10.1080/09637480120091982

Amira, E., Flamini, G., Saafi, E. B., Issaoui, M., Zeyene, N., Ferchichi, A., Hammami, M., Hedal, A. N., Achour, L. (2011). Chemical and aroma volatile compositions of date palm fruits at three maturation stages. *Food Chemistry, 127*, 1744-1754. https://doi.org/10.1016/j.foodchem.2011.02.051

Chafi, A., Benabbes, R., Bouakka, M., Hakkou, A., Kouddane, N., Berrichi, A. (2015). Pomological study of dates of some date palm varieties cultivated in Figuig oasis. *Journal of Materials and Environmental Science, 6*(5), 1266-1275.

Dransfield, J., Uhl, N. W., Asmussen, C. B., Baker, W. J., Harley, M. M., Lewis, C. E. (2008). *Genera Palmarum, the evolution and classification of palms*. Kew, UK, Kew: Royal Botanic Gardens.

Elguerrouj, M., Paquot, M., Robert, C., Benjouad, A., Bouakka, M., Hakkou, A. (2011). Physicochemical composition of two varieties of Moroccan palm date fruit. *Asian Journal of Chemistry, 23*, 1932–1936.

El-Otmani, M., Bagayogo, S., El-Fadl, A., Benismail, M. C. (2015). Effect of regulated deficit irrigation on vegetative growth, fruiting, stomatal conductance and water use efficiency in 'nules' clementine under arid conditions of the souss valley of morocco. *Acta Horticulturae, 1065*, 1757-1766. https://doi.org/10.17660/ActaHortic.2015.1065.225

Fadel, M. A., Kurmestegy, L, Rashed, M., Rashed, Z. (2006). Fruit color properties of different cultivars of dates (*Phoenix dactylifera* L.). *Agricultural Engineering International CIGR Journal, 3*, 1-9.

Hasnaoui, A., Elhoumaizi, M. A., Hakkou, A., Wathelet, B., Sindic, M. (2010). Physico-chemical characterization, classification and quality evaluation of date palm fruits of some Moroccan cultivars. *Biology Journal of Scientific Research, 3*(1), 139-149. https://doi.org/10.3329/jsr.v3i1.6062

Lobo, M. G., Elhadi, M. Y., Kader, A. A. (2013). Biology and postharvest physiology of date Fruit. In M. Siddiq, S. M. Aleid & A. A. Kader (Eds.), *Dates: Postharvest science, processing technology and health benefits* (pp. 57-80). UK, John Wiley & Sons Ltd Publisher. https://doi.org/10.1002/9781118292419.ch3

Mansour, H. M. (2005). *Morphological and genetic characterization of some common Phoenix dactlifera L. cultivars in Ismailia region*. M.Sc. Thesis. Suez Canal University, Faculty of Science, Department of Botany, Egypt.

Marondedze, C., Gehring, C., Thomas, L. (2014). Dynamic changes in the date palm fruit proteome during development and ripening. *Horticulture Research, 1*, 1-14. https://doi.org/10.1038/hortres.2014.39

ORMVAT (2015). *Bilan Phoenicicole au titre de la compagne agricole 2014-2015.* Office Régional de Mise en Valeur Agricole de Tafilalet (ORMVAT).

Rastegar, S., Rahemi, M., Baghizadeh, A., Gholami, M. (2012). Enzyme activity and biochemical changes of three date palm cultivars with different softening pattern during ripening. *Food Chemistry, 134*, 1279-1286. https://doi.org/10.1016/j.foodchem.2012.02.208

Salman Haidar, M., Iqrar, A. K., Summar, A. N., Jaskani, M. J., Rashad, W. K., Nafees, M., … Pasha, I. (2013). Fruit developmental stages effects on biochemical attributes in date palm. *Pakistan Journal of Agricultural Scences, 50*(4), 577-583.

Shengji, P., Sanyang, C., Lixiu, G., Henderson, A. (2010). *Phoenix* Linnaeus. *Flora China, 23*,143-144.