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Effect of chemical thinning on the fruit parameters of 'Majhoul' date palm during fruit development

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Abstract

The aim of this work was to study the effect of NAA (Naphthalene acetic acid) on the chemical thinning of 'Majhoul' date palm in order to use this operation as an alternative to manual thinning, which is a costly operation carried out by the farmers. Experiments were carried out on an adult plantation of 'Majhoul' cv in Tafilalet area. Thinning treatments used were T0 (control treated with water), T1 (application of 150 and 300 ppm NAA 30 and 60 days after pollination), T2 (application of 250 and 500 ppm NAA 30 and 60 days after pollination) and T3 (manual thinning performed by the farmer). These treatments were used on three flowering phases of this variety. Obtained results showed that for the early flowering phase, T2 NAA treatment increased fruit drop for 77% compared to the control. Thinning treatments T1, T2 and T3 yielded fruit with larger size (fruit mass of 17.26, 18.51 and 20.88 g respectively) than that of the control (13.67 g). The late flowering phase also gave fruit with larger size (fruit mass of 18.73 g and fruit length of 4.44 cm) than that of the other flowering phases (fruit mass of 17 g and fruit length of 4.34 cm for the other flowering phases).

Keywords: Date palm; Majhoul cv; Fruit thinning; Naphtalen acetic acid; Fruit drop; Flowering phase; Fruit size

1. Introduction

Date production in Morocco is over 102,000 tons and Draa-Tafilalet area is the main production area [1]. More than 223 varieties of date palm are described in Morocco and the very known commercial varieties are 'Majhoul', 'Boufegous', 'Bouskri', 'Nejda' and 'Jihel', which represent only 36.1% of the national heritage [2]. The flowering of date palm is an irregular phenomenon, which can spread over a period of 30 to 50 days [3] and in three flowering phases. These flowering phases are early flowering, seasonal and late phases. They have an influence on fruit development and fruit quality and on the ripening time [4, 5]. Fruit development is spreading over five successive stages known as 'Hababouk', 'Kimri', 'Khalal', 'Rutab' and 'Tamar' [6]. 'Majhoul' date has the largest size among date varieties (fruit mass: 19.33 g, fruit length: 5.80 cm and fruit diameter: 2 cm) [7, 8]. According to Arba et al. [5], the fruits of the early flowering phase have a larger size (fruit mass: 22.43 g and fruit length: 4.87 cm) than that of the other flowering phases (fruit mass: 13.32 and 9.44 g and fruit length: 3.98 and 2.95 cm respectively for the seasonal and late flowering phases). This is partly due to the lower fruit load of the clusters of the early flowering phase compared to the clusters of the other flowering phases. In the other hand, the large size of the fruits of the early flowering phase is also due to fruit growth of

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the early flowering phase, which is 11 to 15 days earlier than the seasonal flowering and 28 to 31 days earlier than the late flowering phase [5].

The thinning practice is very determinant in the fruit quality of date palm and two types of thinning are used in date palm : reducing the number of clusters per palm or limiting clusters and reducing the number of fruits per cluster or fruit thinning. This late thinning practice can be done by reducing the number of fruits or the number and/or the length of spikelets per cluster [9]. The thinning operation is often practiced after fruit set. It improves fruit yield and quality and avoids the phenomenon of alternation [9, 10]. The limitation of clusters may be practiced 3 to 4 weeks after fruit set, and the number of clusters to be eliminated must respect a balance of one cluster per 10 to 12 palms and the clusters to be eliminated are those in excess and poorly formed [9, 11]. Ben Salah et al. [12] reported that removing 25% of spikelets per cluster and reducing their length in 'Khalas' and 'Barhee' cvs improved fruit mass by 34% compared to not thinned control, but the response of the two varieties to these thinning methods is different. 'Khalas' cv performed well by reducing the length of spikelets, while 'Barhee' cv performed well by removing 25 % of spikelets per cluster . Samouni et al. [13] also reported that the removal of 15, 30, or 45% fruit per cluster improved fruit and pulp mass of these varieties.

Chemical thinning in date palm has been the subject of several research studies using various products and some of them, mainly NAA, are used to improve fruit yield and quality [14, 15]. An application of 50, 100, 150 and 200 ppm NAA on 'Barhee' and 'Shahl' date palm ten weeks after fruit set increased the cluster mass and fruit size [16] and an application of 100 and 300 ppm NAA on 'Succury' date palm 30 days after pollination also increased fruit size by causing a considerable fruit drop [17]. El-Kosary [18] reported that the application of 75 ppm Cytophex (CPU, 2-chloro-4-oridyl phenyl) on 'Sumary' and 'Zaghloul' date palm four weeks after pollination increased fruit size and Davis [26] indicated that growth regulators play an important role in the improvement of fruit growth and development even in the absence of the thinning operation. Application of 50, 100 and 150 ppm NAA on 'Sumary' and 'Zaghloul' date palm four weeks after pollination resulted in fruit drop and 150 ppm increased the drop by 12% compared to untreated control. Similarly, application of 150 ppm NAA on 'Khanazy' date palm 45 days after pollination resulted in fruit drop, whereas its application 90-135 days after pollination reduced fruit drop [14]. El-Kosary [19] also reported that an application of high NAA concentrations (100, 500, 1000 and 1500 ppm) on 'Zahidi' date palm 15 and 30 days after pollination resulted in a significant fruit drop, while an application of low concentrations (10 and 15 ppm) does not effect fruit drop. NAA treatment may be influenced by the product concentration, the amount of porridge used, the fruit development stage, and the climatic conditions during the application of NAA [20]. Some authors have even suggested that the application of NAA should be postponed once the temperature is above 29 °C [21] and Al-Obeed et al. [22] reported that the best period for NAA application is between 15 and 30 days after pollination.

Fruit thinning is an important practice in date palm production, but the farmers are using a manual practice, which is expensive due to its labor intensive [9]. So that, research should be directed towards alternatives that can replace this manual operation, mainly chemical thinning using synthetic products such as NAA, which has been shown to be effective in date palm [16]. The aim of our research work is to study the effect of the application of NAA on fruit thinning of 'Majhoul' date palm in order to reduce the cost of production to farmers and to obtain sufficient production with good quality fruits .

2. Materials and methods

To meet these objectives, NAA treatments have been applied on the fruits of the early flowering, seasonal and late phases of date 'Majhoul' date palm in order to study their effect on fruit thinning and on the evolution of the fruit morphological parameters during fruit development. Trials were carried out on an adult plantation (15 years old) of 'Majhoul' date palm in the Tinejdad region, Tafilalet area: 31° 32' N, 4° 52' W, 1062 m altitude. The climate of the site of trials is characterized by high temperatures in summer (a mean of 42 °C) and low temperatures in winter (a mean of -0.5 °C), low rainfall (less than 100 mm per year), which is poorly distributed over time. The site of trials is also known by its warm and dry winds from the east, which can reach more than 57 km h^{-1} during the months of May to August [23]. The soil of the site plot is 46% fine sand, 30% silt, 12% clay, 7% limestone and 0.21% organic matter. Drip irrigation is the irrigation system used in the farm of trials, two drip ramps are used per row, and two drippers are used per palm tree (one dripper per drip ramp). The organic manure is brought once a year, in May, the quantity brought is 150 kg per palm tree, and mineral manure is brought twice a year, during the months of February and June. Both manures are spread in the palm bowl, followed by hoeing and irrigation to escape the manures into the soil and dissolve the mineral fertilizers in water. Watering and fertilizing programs of 'Majhoul' date palm in the farm of trials are presented in Table 1.

Studied palm trees are 2 to 3 m high, the number of palms per palm tree is 72 to 80 and the number of clusters per palm is 11 to 16, depending on the cluster load and a balance of 10 palms per cluster . The experimental design adopted is a split-plot with two factors: the flowering phase and thinning treatment. It is formed of 3 blocks, with 4 palm trees per block, and on each tree the three flowering phases are randomly chosen. The opening periods of the spathes of the three flowering phases are presented in Table 2. The number of flowers per cluster is determined from the number of flowers of 5 spikelet which are randomly selected and multiplied by the number of spikelets per cluster . Moreover, the latter value was determined from the number of spikelet on 3 clusters which are randomly selected from each flowering phase (Table 2).

Table 1 Watering and fertilizing programs for 'Majhoul' date palm in the farm of trials in the Tinejdad region, Tafilalet area, Morocco

Fertilizing program				**Watering program**	
Used fertilizers	Main constituents	Brought amount per palm tree in February	Brought amount per palm tree in Jun	Watering dose per palm tree and watering frequency	Watering periods
Composed fertilizer	14% N, 7% P_2O_5, 21% K_2O, 3% MgO	2 kg (0,28 kg N, 0,14 kg P_2O_5, 0,42 K_2O et 0,06 kg MgO)	1 kg (0,14 kg N, 0,07 kg P_2O_5, 0,21 K_2O et 0,03 kg MgO)		
Silica-based fertilizers	60% SiO_2, 3,7% MgO, 3,4% Fe_2O_3, 3% CaO	1 Kg (0,6 kg SiO_2, 0,037 kg MgO, 0,034 kg Fe_2O_3, 0,03 kg CaO)	1 Kg (0,6 kg SiO_2, 0,037 kg MgO, 0,034 kg Fe_2O_3, 0,03 kg CaO)	400 to 600 l/palm tree/4 days	December to April
Ammonium nitrate	33,5% N	2kg (0,67 kg N)	1kg (0,335 kg N)		
Potash nitrate	13 % N, 46% K_2O	-	1kg (0,13 kg N, 0,46 kg K_2O)	400 to 600 l/palm tree/2 days	May to November
DAP Diammonium-triphosphate	18% N, 46% P_2O_5	1kg (0,18 kg N, 0,46 kg P_2O_5)	-		

Table 2 Number of flowers per spikelet and of spikelets per cluster and flowering phase, flowering and pollination periods of the three flowering phases (early flowering, seasonal and late phases), thinning treatments used and dates of application of NAA on 'Majhou:date palm in the Tinejdad region, Tafilalet area

	Flowering phase			
	Early flowering	**Seasonal flowering**	**Late flowering**	
Number of spikelets per cluster	70,00 ± 4,00 a	64,00 ± 6,00 a	52,00 ± 3,00 b	*
Number of flowers per spikelet	48,00 ± 2,63 a	39,00 ± 2,00 b	33,00 ± 2,00 c	*
Spikelet length (cm)	50,00 ± 1,46 a	40,95 ± 2,25 b	35,49 ± 1,33 c	*
Opening period of the spathes	15 to 25 March	26 March to 5 April	Beyond April 5	
Pollination period	March 30 to April 6 2017	April 7 to 14 2017	April 15 to 21 2017	
	T0	Control treated with water 30 and 60 days after pollination		

Thinning treatments used	T1	Application of 150 and 300 ppm NAA 30 and 60 days after pollination
	T2	Application of 250 and 500 ppm NAA 30 and 60 days after pollination
	T3	Fruit thinning practiced by the farmer: leave only 8-10 fruits per spikelet
Dates of application of NAA	First application	May 8 2017, 30 days after pollination of the early flowering phase
	Second application	Jun 10 2017, 60 days after pollination of the early flowering phase

* significant difference at $p \leq 0{,}001$

The pollination period of each flowering phase is presented in Table 2 and the pollination consists of placing three male spicklet of inflorescence in the center of the female inflorescence. Thinning treatments used and the dates of application of NAA are presented in Table 2. Manual thinning began on May 15, 2017, 45 days after pollination and fruit diameter at this stage was 1.2 to 1.3 cm. It is used to evaluate the effectiveness of chemical thinning with NAA. Fruit diameter during the first NAA treatment was 0.8 cm for the early flowering phase, 0.65 cm for the seasonal and 0.5 cm for the late flowering phase and fruit diameter at the second treatment was 2.2 cm for the early flowering phase, 2 cm for the seasonal and 1.8 cm for the late flowering phase. Each palm tree of the trials is subjected to one thinning treatment, which is repeated three times per flowering phase in the three blocks of the experimental design. Measures should be considered when treating NAA because this product is sensitive to climatic conditions. The mean temperature should be between 18 and 24 °C, the relative humidity between 5 and 17% and the wind speed should not exceed 5 km per hour. The NAA product used is a powder with a purity of 99% and the quantities used are measured with a precision balance having an error of 0.01 mg.

After pollination, the rate of fruit set is reported first, by counting the number of flowers and set fruits per spikelet among the cluster , which are marked on each cluster . The marked spikelet are randomly selected as follows: 2 in the basal part of the cluster , 2 in the center and 1 in the upper part. Fruit samples are taken and measurements are made every 15 days, and measured parameters included the fruit morphological parameters (fruit mass and size and fruit dimensions) on a sample of 3 fruits per flowering phase, and per thinning treatment and block (108 fruits in total). Fruit measurements began on May 8, 2017, fruit dimensions are measured with a caliper and fruit mass with a precision balance having an error of 0.01 mg. Fruit size (volume) is determined using a measuring cylinder according to the following formula:

$$\text{Fruit size (cm3)} = \frac{\text{V1 (cm3)} - \text{V0 (cm3)}}{3}$$

V0: volume of water in the measuring cylinder before putting the fruit into the cylinder

V1: volume of water in the measuring cylinder after putting the fruit into the cylinder

Acourene et al. (2001) classified fruit dates of 'Majhoul' date palm in three sizes: large size: fruit length: 4 cm and fruit mass 8 g; medium size: fruit length between 3.5 and 4 cm and fruit mass between 6 and 8 g; and small size: fruit length: less than 3.5 cm and fruit mass: less than 6 g. Moreover, according to Sabri et al. [24], 'Majhoul' dates are classified into three commercial sizes: extra size: fruit mass of 19.20 g or more; first class size: fruit mass between 10.50 and 19.20 g; and second class size: fruit mass between 9 and 10.50 g.

The following of the fruit set began one week after the application of NAA treatments. It is carried out every week on spikelet, which are marked by cluster and for each flowering phase. The rates of fruit set and fruit drop are determined according to the following formulas:

$$\text{The rate of fruit set (\%)} = \frac{\text{Number of flowers transformed into fruit}}{\text{Number of total flowers}} \text{ x } 100$$

$$\text{The rate of fruit drop (\%)} = \frac{\text{Number of drpped fruits}}{\text{Number of knotted fruits}} \text{ x } 100$$

Statistical analysis of data is performed with the Minitab 16 software, the determination of the mean is performed with ANOVA with a single factor and the comparison of the means is performed with the Tukey test having 5% acuracy.

3. Results and discussion

3.1. Effect of the application of NAA on fruit drop

The period of observations on fruit drop lasted 70 days. It extends from May 8 to July 14, 2017. The evolution of fruit drop by NAA treatment is presented in Figure 1. It shows that for the period following the first application of NAA, which extends for about one month (from May 8 to June 9, 2017), fruit drop per spikelet is for 2 fruits per week for T1 and T2 treatments and total fruit drop for the period of observations is respectively 8 and 9 fruits per spikelet. While for the period following the second application of NAA, which also extends for about one month, there is a regression in fruit drop (1 fruit per spikelet per week for T2 and almost negligible fruit drop for T1).

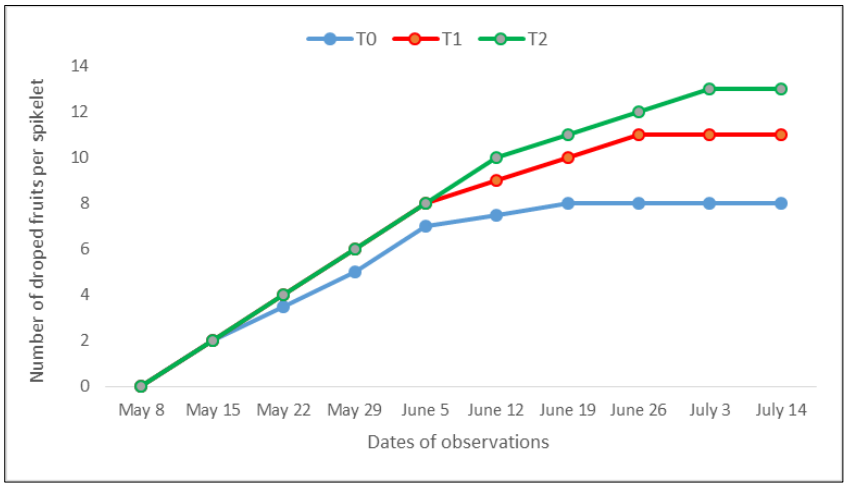

Figure 1 Fruit drop evolution of 'Majhoul' date palm per NAA treatment: T0 (clear water), T1 (150 and 300 ppm NAA 30 and 60 days after pollination), and T2 (250 and 500 ppm NAA 30 and 60 days after pollination) in the Tinejdad region, Tafilalet area

At the end of observations, the number of dropped fruit per NAA treatment and flowering phase is presented in Table 3 and statistical analysis of data showed a significant difference ($p \leq 0.05$) between NAA treatments and flowering phases, but there is no interaction between the two factors. Fruit drop was higher at the late flowering phase with a rate of 49%, followed by the early flowering phase with 44% and the seasonal phase with 40%. This is due to fact that fruits of the late flowering phase received a high concentration of T2 NAA treatment during the early stage of their development and the fruits of the early flowering phase received T1 NAA treatment during the first stage of their development. The best timing for the application of NAA is 30 days after pollination with high NAA concentrations (Table 3). Several authors also reported that application of medium NAA concentrations (50 to 150 ppm on 'Sumury', 'Zaghloul' and 'Khanazi' date palm) or high NAA concentrations (100 to 100 ppm on 'Zahidi' date palm) 15 to 45 days after pollination resulted in fruit drop [14, 19]. While the application of low NAA concentrations (10 to 15 ppm) does not affect fruit drop [19]. According to some authors, the best period for the application of NAA should not exceed 30 days after pollination because it is during the first stage of fruit development when fruit drop is favored by the small size of the fruits [14, 17, 22]. The rate of fruit drop during the first NAA treatment (8 May 2017) is presented in Table 3.

Table 3 Fruit set and fruit drop and retained fruits per cluster , per NAA treatment (T0, T1 and T2) and per flowering phase of 'Majhoul' date palm in the Tinejdad region , Tafilalet area

	Final number of dropped fruits per cluster	**Final number of retained fruits per cluster**	**The rate of fruit drop (%)**	**Number of knotted fruits per cluster**	**The rate of fruit set on May 8 2017 (%)**
Flowering phase					
Early flowering	1083 ± 23	1362 ± 29	44 ± 0.6	2445 ± 56	71 ± 1.4
Seasonal flowering	640 ± 13	959 ± 18	40 ± 0.8	1600 ± 36	60 ± 1.2
Late flowering	408 ± 7	420 ± 7	49 ± 1	830 ± 17	52 ± 1
NAA treatment					
T0	493 ± 8	873 ± 15	36 ± 0.8		
T1	763 ± 15	897 ± 20	56 ± 1.2		
T2	875 ± 16	871 ± 15	50 ± 1		

After the stabilization of fruit drop, the number of retained fruits per NAA treatment and flowering phase is presented in Table 3 and statistical analysis of data showed no significant difference ($p > 0.05$) between NAA treatments, whereas the difference is significant ($p \leq 0.05$) between the flowering phases. For the manual thinning, the number of retained fruits per cluster is 630, 576 and 468 respectively for the early flowering, seasonal and late phases. These results may be explained partially by the difference in fruit size between flowering phases during NAA treatments. Fruit diameter was 8 mm for T1 treatment and 22 mm for T2 treatment for the early flowering phase, 6.5 mm for T1 and 20 mm for T2 for the seasonal phase and 5 mm for T1 and 18 mm for T2 for the late flowering phase. On the other hand, by the difference in the initial fruit load of clusters , which is higher in the early flowering phase, followed by the seasonal phase and the late flowering phase is the last (Table 3). The difference in the clusters initial loading between the flowering phases is due to the difference in the number of spikelet and flowers per cluster and in the rate of fruit set between these flowering phases (Table 3). Further statistical analysis of data has shown a linear correlation between the initial cluter load and the number of retained fruits per cluster or final cluster load and $R^2 = 0.91$ (Figure 2). The relationship between the initial and final cluster load is increasing and the greater the initial load, the greater the final one.

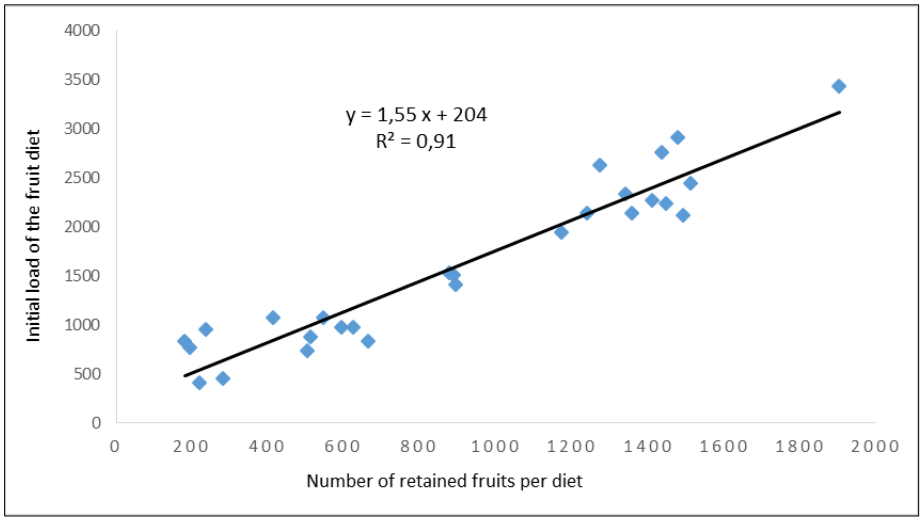

Figure 2 Relationship between the initial and final load of the fruit cluster after thinning treatments in 'Majhoul' date palm in the Tinejdad region, Tafilalet area, Morocco.

Moreover, according to the equation of this linear relation, the initial load of the cluster may be obtained from its final load according to the following formula:

Initial fruit load = 204 + 1.55 x final fruit load

Based on a manual thinning where the number of retained fruits per spikelet is 10, the initial load of the cluster will be obtained for each flowering phase. In the case of the early flowering phase, for example, knowing that the number of spikelet per cluster is 70 (Table 2) and the final load of the cluster is 700 fruits (70 x 10), we can obtain an initial load of 1290 fruits according to the previous equation. Knowing that the number of flowers per spikelet is 48 (Table 2), this initial load can inform us about the rate of fruit set according to the following formula:

The rate of fruit set (%) = 1290/48 x 70 = 38%

3.2. Effect of fruit thinning and flowering phase on fruit quality

3.2.1. Effect on fruit mass and fruit size

Figure 3 presents the evolution of fruit mass and size of 'Majhoul' date palm in relation to thinning treatments and flowering phases during the fruit development period. It shows a relative sigmoidal form for both factors, with a small increase in the beginning of the fruit growth which is followed by an exponential increase and subsequently by a stabilization which often ends with a slight decrease. Fruit mass and size showed a similar evolution for all the thinning treatments until June 12 2017 (60 days after pollination) and from this date the difference between treatments began to appear, with thinning treatments being superior to the control (Figure 3a and b).

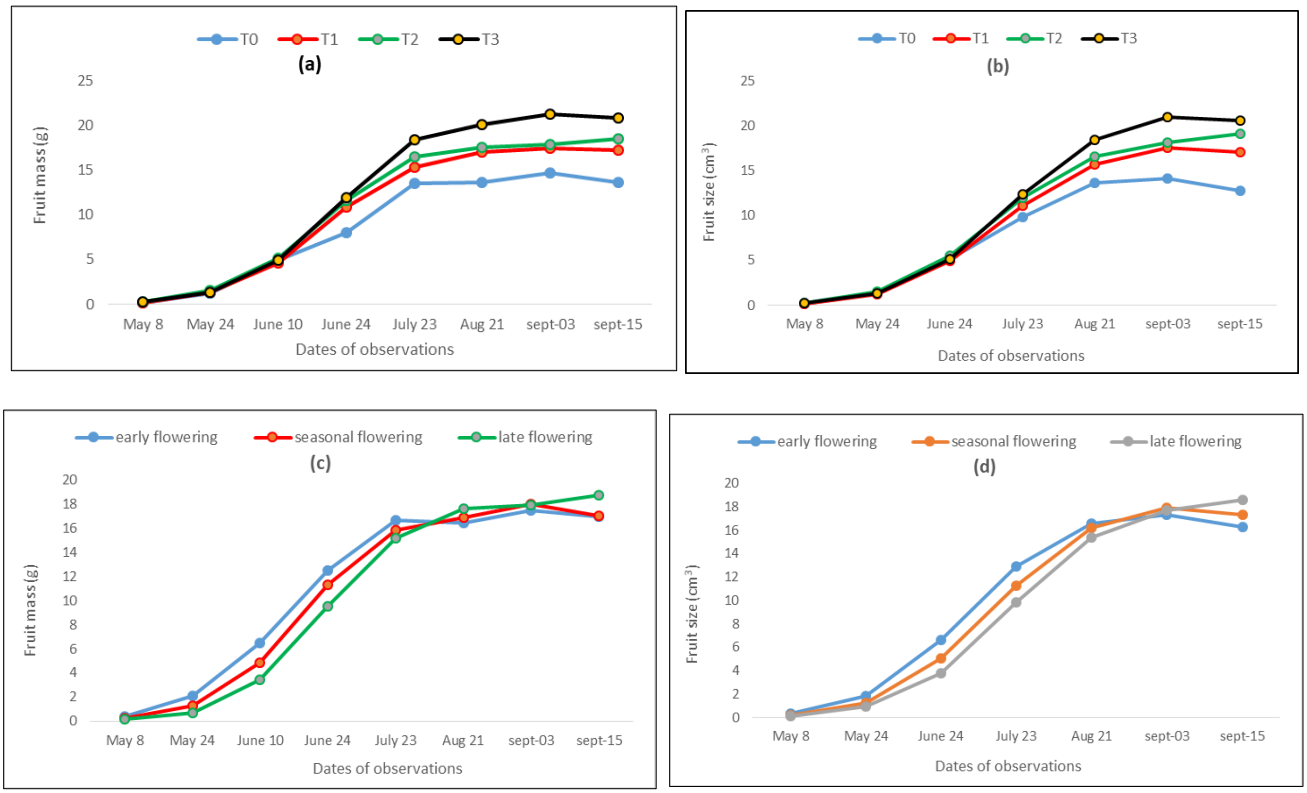

Figure 3 Evolution of the fruit mass and size of 'Majhoul' date palm in relation to T0, T1, T2 NAA treatments and manual thinning T3 used by the farmer (a and b) and flowering phases (early flowering, seasonal and late phases) (c and d) in the Tinejdad region, Tafilalet area

At the end of observations, which coincide with the beginning of the 'Rutab' stage, the final fruit mass and size are presented in Table 4 and statistical analysis of data has shown a significant difference ($p \leq 0.001$) between thinning treatments for these two parameters. Regarding the flowering phases, the early flowering phase showed a superiority over the other phases until July 10 2017 and from this date, there is a similar and stable evolution of the three flowering phases until August 10, 2017. Thereafter, fruit mass of the early flowering and seasonal phases begins to decrease and

that of the late flowering phase begins to increase (Figure 3c and d), but the final fruit mass and size does not show any significant difference ($p > 0.05$) between the flowering phases (Table 4). There is also no interaction between thinning treatments and flowering phases for fruit mass and size.

Table 4 Final values of the morphological parameters of the fruit of 'Majhoul' date palm in relation to fruit thinning treatments (T0, T1, T2 et T3) and the three flowering phases (early flowering, seasonal and late phases) in the Tinejdad region, Tafilalet area

Morphological parameters	**Thinning treatment**					**Flowering phase**			
	T0	**T1**	**T2**	**T3**		**Early**	**Seasonal**	**Late**	
Fruit mass (g)	13.67 ±1.51	17.26 ± 2.81	18.51 ± 2.13	20.88 ± 2.15	**	16.97 ± 1.70	17.03 ± 2.56	18.73 ± 2.74	ns
Pulp mass (g)	10.40 ±1.45	13.97 ± 1.48	14.92 ± 1.96	17.11 ± 1.83	**	13.63 ± 1.68	13.56 ± 2.31 a	15.11 ± 2.41	ns
Seed mass (g)	3.27 ± 0.29	3.29 ± 0.48	3.59 ± 0.21	3.77 ± 0.40	ns	3.34 ± 0.26	3.48 ± 0.32	3.62 ± 0.39	ns
Fruit size (volume) (cm^3)	12.81 ± 1.28	17.15 ± 2.78	19.19 ± 2.28	20.67 ± 2.47	**	17.36 ± 1.72	16.36 ± 2.80	18.67 ± 2.94	ns
Fruit length (cm)	3.93 ± 0.15	4.38 ± 0.19	4.52 ± 0.18	4.68 ± 0.18	**	4.34 ± 0.15	4.34 ± 0.22	4.49 ± 0.27	ns
Fruit diameter (cm)	2.35 ± 0.05	2.62 ± 0.12	2.74 ± 0.2	2.84 ± 0.12	**	2.59 ± 0.11	2.63 ± 0.12	2.60 ± 0.11	*

*: Significant difference at $p \leq 0.05$; **: significant difference at $p \leq 0.01$; ns: no significant difference; T0 (clear water); T1 (150 and 300 ppm NAA 30 and 60 days after pollination); T2 (250 and 500 ppm NAA 30 and 60 days after pollination); T3 (manual thinning used by the farmer)

Our results are in concordance with those of Al-Obeed et al. [17] who reported that the application of 100 and 300 ppm NAA on the 'Succury' date palm 30 days after pollination increased fruit size by causing a considerable fruit drop. Harbash & Al-Obeed [16] also indicated that the application of 50, 100, 150 and 200 ppm NAA on 'Barhee' and 'Shahe' date palm ten weeks after fruit set increased the cluster mass and fruit size. Some other authors also reported that NAA is used to improve fruit yield and quality of date palm [15]. The difference in fruit mass and size between thinning treatments may be due to the difference in the cluster fruit load since the clusters of manual thinning and NAA treatments are less loaded than the clusters of the control. Regarding fruit mass and size in relation to flowering phases, our results are different from those of Arba et al. [5] . They reported that fruit mass and size of the early flowering phase are higher than those of the other flowering phases and this is due to the fact that the clusters of the early flowering phase in their study are less loaded than those of our study. According to Acourene et al. [25] , the fruits of all the thinning treatments, including the control, and of all the flowering phases may be considered large size (fruit mass: 8 g). Moreover, according to the commercial standards of 'Majhoul' dates [24], the fruits of T3 treatment can be classified in the extra commercial size (fruit mass > 19.5 g) and those of T0, T1 and T2 treatments and of all the flowering phases may be classified in the first commercial class (fruit mass between 10.50 and 19.20 g). Several authors also reported that 'Majhoul' date has the largest size among date varieties [7, 8].

3.2.2. Effect on fruit dimensions

The evolution of the fruit dimensions (fruit length and diameter) in relation to thinning treatments and flowering phases during fruit development is presented in Figure 4. It shows that fruit length and diameter have a similar evolution for all the thinning treatments until July 10 2017 for fruit length and until end of July for fruit diameter. Moreover, from these dates until the end of the observations, fruit length and diameter of T1, T2 and T3 treatments are slightly higher than those of the control, which have experienced a stable evolution (Figure 4a and b). The flowering phases also have an influence on the evolution of fruit length and diameter until the end of June for fruit diameter and the end of July for fruit length and the early flowering phase showed a superiority compared to other flowering phases. It is followed by the seasonal flowering phase. Moreover, from the end of July until the end of the observations, the evolution of the fruit dimensions is similar and stable for all the flowering phases (Figure 4c and d). The final fruit dimensions in relation to fruit thinning treatments and flowering phases are presented in Table 4 and statistical analysis of data showed a significant difference ($p \leq 0.05$) between thinning treatments for fruit dimensions and between flowering phases for

fruit diameter. However, there is no significant difference ($p > 0.05$) between flowering phases for fruit length and no interaction between thinning treatments and flowering phases for these parameters.

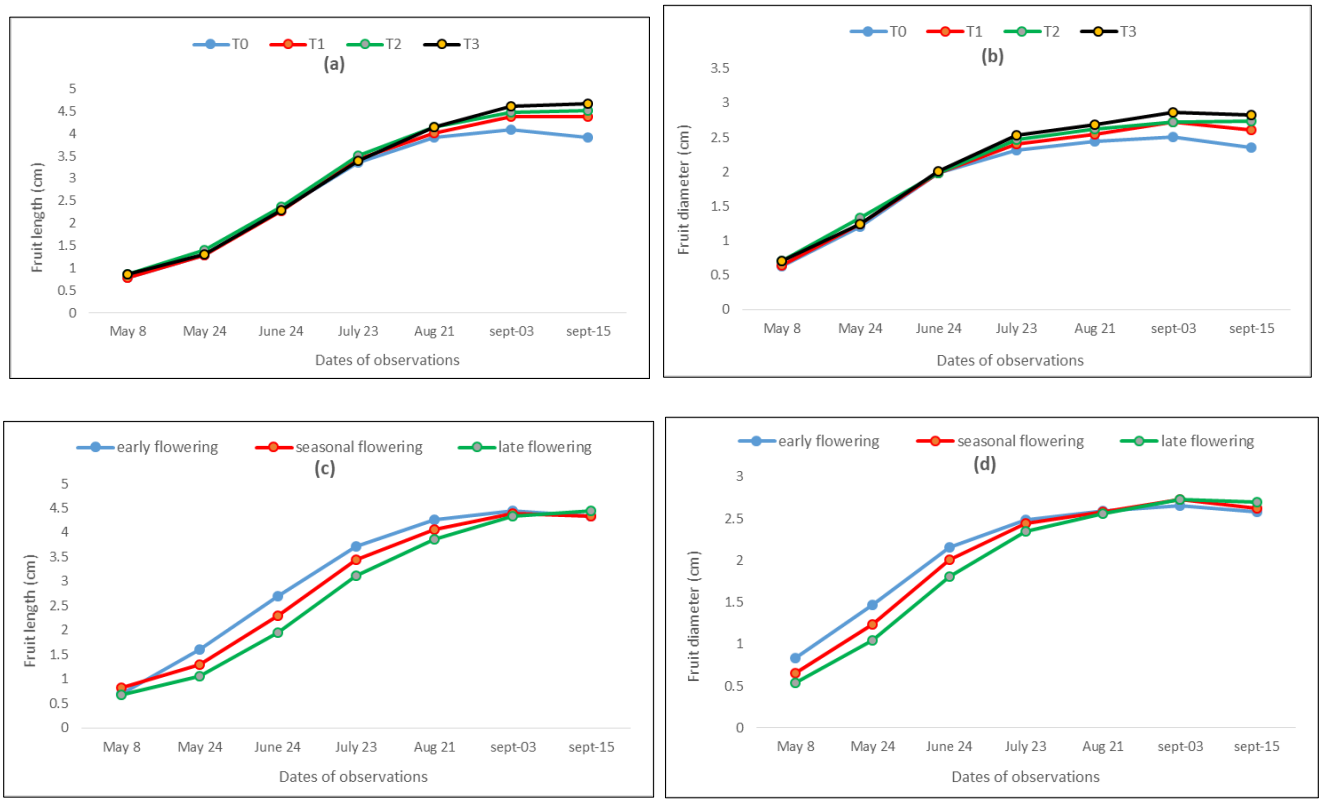

Figure 4 The evolution of fruit length (a and b) and diameter (c and d) in relation toT0, T1, T2 and T3 thinning treatments and the three flowering phases (early flowering, seasonal and late phases) of 'Majhoul' date palm in the Tinejdad region, Tafilalet area

Our results are consistent with those of Al-Obeed et al. [17] and Harbash & Al-Obeed [16] who reported that applying different concentrations of NAA (50 to 300 ppm) 30 days after pollination on the 'Succury' date palm or ten weeks after fruit set on the 'Barhee' and 'Shahe' date palm resulted in an increase in fruit size. Some other authors indicated that the growth regulators improve fruit growth and development of date palm even in the absence of the thinning operation [26]. The difference in the final fruit size between the flowering phases may be explained by the fact that the clusters of the early flowering phase have a higher load than those of the other flowering phases. These results are different from those of Arba et al. [5] who indicated that fruit diameter of the early flowering phase is higher than that of the other flowering phases because in their study the clusters of the early flowering phase are less loaded than those of the other flowering phases. In addition, according to Acourene et al. [25], the fruits of T1, T2 and T3 treatments and those of all the flowering phases are of large size (fruit length > 4 cm) and the fruits of the control T0 are of medium size (fruit length between 3.5 and 4 cm).

4. Conclusion

The recent expansion of the commercial varieties of date palm in Morocco, mainly 'Majhoul' cv, requires the introduction of new management practices which are less costly for the farmer such as chemical thinning to replace the manual one which is economically expensive due to its requirement for skilled labor. Results obtained by applying this practice on 'Majhoul' date palm are encouraging. They showed that fruit drop was higher in T2 treatment with higher concentration of NAA (250 and 500 ppm 30 and 60 days after pollination) compared to other thinning treatments, with 50% for the rate of fruit drop. Fruit drop was also higher in the early flowering phase compared to other flowering phases, with a rate of 44% . Application of NAA also affect significantly the increase of fruit mass, fruit size and dimensions compared to the control.

Moreover, since the application of high NAA concentrations 30 days after pollination gave good results on fruit drop and fruit physical parameters of retained fruits after the drop, further trials using higher NAA concentrations during

this period is required. Trials using chemicals other than NAA and which have been shown to be effective in the chemical thinning of date palm such as Ethephon, Indol-acetic acid and AG3, should be studied on 'Majhoul' date palm in order to compare them with NAA and to obtain reliable results on the chemical thinning of this variety. In the same way, it would be desirable when conducting trials on the chemical thinning to integrate a study on the content of other elements in the fruit, which may influence fruit drop Such as ethylene, auxin and calcium. .

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed

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