



Fruit set in Majhoul date palm and fruit drop by chemical thinning

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Abstract

Date palm is very cultivated in Draa-Tafilalet area (the southeastern part of Morocco). The variety diversity is rich and include commercial varieties such as 'Majhoul' and 'Bouffegous'. Fruit thinning consists of reducing the fruit load of date palm in order to obtain a balance between yield and fruit quality and to avoid alternating production. Naphthalene acetic acid (NAA) spray is used on date palm to induce fruit drop. Chemical thinning with NAA has been the subject of several research studies, which have focused on the effectiveness of the operation, the doses used and the periods of its application. The practice is not yet well mastered in Morocco and its advantages are not well known. Our work aims to study the fruit set and the effect of NAA treatments on fruit drop of 'Majhoul' date palm. Trials were carried out on an adult plantation in Tafilalet area and obtained results showed that fruit set in the early flowering phase was higher (more than 57%) than in the seasonal (55%) and late (42%) phases. Fruit drop is low before the application of NAA (2.41 fruits/spikelet for the seasonal flowering), while it is higher after its application (7.53 fruits/spikelet for the same phase). This is due to the best period chosen for the first application of NAA (100 ppm) and which favored fruit drop during the first stage of fruit development. The second application of NAA (200 ppm), even with a double dose than the first application, did not significantly affect fruit drop because the fruits are in an advanced stage of their development.

Keywords: Date palm; Majhoul cv; Fruit set; Chemical thinning; Fruit drop

1 Introduction

The cultivation of date palm is practiced over the world (Africa, North and South America, Asia) and date production is carried out mainly in the Middle East and North Africa countries, which provide 90% worldwide production [1, 2]. The production has increased remarkably over the last decade to reach 9 million tons. Egypt ranks first with 1.5 million tons and Iran second with 1.2 million tons [3]. Current date production in Morocco is over 102,000 tons and date palm area is 60,000 ha [4]. In this country, the southeastern part, especially Draa-Tafilalet area, is the main production area where the date industry plays an important socio-economic role [4, 5]. Morocco also includes a rich diversity with more than 453 varieties and some of them are known as commercial varieties such as 'Majhoul', 'Bouffegous', 'Bouskri', 'Nejda' and 'Jihel' [4].

Date palm is a dioecious species whose pollination plays an important role in fruit yield and quality due to its human-induced operation which affects fruit set [6, 7, 8, 9], and improved fruit set improves yield and fruit quality [10]. So that, measures must be taken when pollinating date palm, in particular the receptivity period of the female flowers, the source of pollen used and the flowering periods of the pollinator and the female variety to be pollinated, which must overlap [8, 11]. Fruit thinning involves the reduction of the number of fruits on loaded clusters when fruit size is still

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small, in order to achieve a balance between production and date quality and to avoid the alternating production [12]. Fruit thinning consists in reducing the number of fruits per spikelet or the number of spikelets per cluster and/or reducing their length, in order to improve the development of kept fruits. Cluster limitation is a pruning operation which consists of reducing the number of clusters per palm tree by cutting those which are not well formed in order to achieve a balance between the number of diets and palms and between production and date quality, and to avoid the alternating production. It is carried out just after fruit set and the number of clusters to be kept per palm tree can vary according to the age of palm tree, the number of palms per tree, and water and mineral nutrition of the palm tree.

A series of natural fruit drop can occur on a fruit tree. It may concern unfertilized flowers, young knotted and poorly fertilized fruits, fruits that are less competitive during fruit drop of June and July and sometimes even fruits at the end of their development and before ripening. Naphthalene acetic acid (NAA) is a synthetic hormone used in the chemical thinning and has the added advantage of having no insecticidal effect, making it harmless to micro fauna [13]. In apple tree, the period of application of NAA is determined based on fruit size after fruit set and the number of days after flowering. In date palm, several authors have shown that applying NAA at the 'Hababouk' stage (20-30 days after pollination) improves fruit drop and fruit yield and quality of retained fruits [14, 15]. Temperatures of 15-18 °C, high relative humidity of more than 80%, and non-sunny weather (because NAA is photodegradable) are the favorable climatic conditions for the application of NAA [13]. Chemical thinning has been the subject of several research studies in developed countries since the 1930s. The research has focused on the evaluation of the thinning qualities of various chemicals, the period of their application, the doses used and the mode of their action. In developing countries this practice is not yet well mastered and its advantages are often unknown [13]. The objectives of this research work are to study the fruit set in 'Majhoul' date palm after pollination and to assess the effect of the application of NAA after pollination (chemical thinning) on fruit drop of this species.

2 Material and methods

2.1 Climatic conditions and soil characteristics of the site of trials

Table 1 Opening periods of female spathes, pollination periods of the three flowering phases (early flowering, seasonal and late phases) and NAA chemical thinning treatments used in 'Majhoul' date palm in the Tinejdad region, Tafilalet area, Morocco

Flowering phase	Opening periods of female spathes	Pollination periods	NAA treatments	Dose of NAA used in porridge (mg l ⁻¹)	Capacity of the sprayer used (l)	Dose of NAA used in the porridge (mg)
Early flowering	25-29 March 2017	April 01 2017	T1 (100 ppm)	0.1	5	0.5
Seasonal	02-09 April 2017	7 and 12 April 2017	T2 (200 ppm)	0.2	5	1
Late flowering	12-17 April 2017	19-20 April 2017				

Trials were carried out on an eight-year-old plantation of 'Majhoul' date palm in the Tinejdad region, Tafilalet area: latitude 31° 32' N, 4° 52' W, altitude 1062 m. Average temperature in the site of trials can reach 40 °C in July and 2 °C in January. The relative humidity varies from 16% in January to 54% in July and average rainfall is 105 mm. The soil of the site of trials has a sandy-silty texture with 55% sand, 31% silt and 12% clay and a limestone content of 6%. Its content in organic matter is low (0.21%) and its pH is 6.95. The planting density in the farm of trials is 6 m between rows and 6 m between trees in the row (277 plants per ha) and studied palm trees are free of serious diseases such as 'Bayoud' and mineral deficiencies. The experimental design used in the study is a split plot with two factors (flowering phase and thinning treatment), three blocks (repetitions), three thinning treatments per block and three flowering phases per thinning treatment, i.e. 27 experimental units. Each experimental unit include two clusters per flowering phase, and on each cluster five spikelet were marked for the monitoring of the observations on fruit set and fruit drop. The blocks are arranged perpendicularly to the gradient of the prevailing winds. The flowering phases studied (early flowering, seasonal and late phases) are determined according to Arba et al. [16]. These last authors have shown also that in 'Majhoul' date palm, fruit dimensions in the three flowering phases are different during the fruit development stages. Opening periods of spathes and pollination periods of the three flowering phases in the studied palm trees are presented in Table 1. The pollination operation of date palm in the farm of trials is carried out manually by placing 3 to 5 spikelet

of mature male inflorescence in the middle of the female inflorescence, holding them with a yaw ligature. Pollen used is from the same male palm 3 to 7 days after the opening of the female spathes. The male inflorescences are harvested 3 to 5 days after the opening of the spathes.

2.2 Measures and observations carried out

2.2.1 Fruit set monitoring

Fruit set monitoring was carried out on the marked spikelet on each cluster of the sample of palm trees and on these spikelet the number of flowers formed is initially counted. Thereafter, knotted flowers, those that are aborted and flowers, which are not yet knotted, are counted every six days. A knotted flower is distinguished by the naked eye; it is characterized by the development of one carpel and the abortion of the two others. The rate of fruit set is determined according to the following formula:

$$\text{The rate of fruit set (\%)} = \frac{\text{Number of knotted flowers}}{\text{Total number of formed flowers}} \times 100$$

Total number of flowers formed on a spikelet = number of knotted flowers + number of aborted flowers + number of flowers not yet knotted + number of scars of dropped flowers before fruit set.

2.2.2 Cluster limitation and fruit thinning

Cluster limitation or reduction in the number of clusters per palm tree is carried out on May 7, 2017, by pruning clusters at an early stage after fruit set. Table 2 shows the status of studied palm trees before and after cluster limitation.

Table 2 Status of studied 'Majhoul' date palm trees before and after cluster limitation in the Tinejdad region, Tafilalet area, Morocco

Block	Date palm trees selected per block	Number of palms per tree	Before cluster limitation		After cluster limitation	
			Number of clusters per palm tree	Number of palms per cluster	Number of clusters per palm tree	Number of palms per cluster
1	1	37	6	6.17	6	6.17
	2	36	7	5.14	6	6.00
	3	41	10	4.1	7	5.86
2	1	44	11	4	8	5.50
	2	47	8	5.88	8	5.88
	3	38	7	6.33	7	5.43
3	1	43	7	6.14	7	6.14
	2	42	8	5.25	7	6.00
	3	46	10	4.6	7	6.57

Fruit thinning is carried out manually. It consists of removing some fruits per cluster in order to promote the development of retained fruits on the cluster. It is carried out on May 16, 2017 for the early flowering phase, May 22, 2017 for the seasonal and June 03, 2017 for the late phase.

2.2.3 Chemical thinning

Naphtalene acetic acid is a synthetic product, which is used in the chemical thinning of date palm. This product is applied in two concentrations: 100 ppm and 200 ppm. NAA treatments used and the composition of the porridge used in a sprayer are presented in Table 1. During the application of NAA treatments, an alcohol-based nonionic active ingredient was added to the porridge with a dose of 1%, to facilitate the uptake of NAA by young fruits. NAA treatments were carried out with a five-liter backpack sprayer and the porridge is applied on the clusters up to the dew point. The application of NAA is carried out at the end of day, when the air is cool and the sun is less intense, in order to avoid rapid drying of the porridge and degradation of the product by sunlight. Climatic conditions during the application of NAA,

NAA treatments used and the characteristics of fruits treated just prior to the application of NAA are presented in Table 3.

Table 3 Climatic conditions during the application of NAA, NAA treatments used and dates of their application and fruit characteristics of 'Majhoul' date palm just before the application of NAA in the Tinejdad region, Tafilalet area

NAA Treatments used	Date of application of NAA treatment	Flowering phase	Fruit mass and dimensions before the application of NAA			Climatic conditions during the application of NAA
			Fruit length (cm)	Fruit diameter (cm)	Fruit mass (g)	
T1 (100 ppm)	May 9 2017	Early flowering	5.69	4.73	0.18	Temperature: 21.6 to 23.5°C Relative humidity: 18 % Wind speed: 3.4 km/h
		Seasonal	5.23	4.35	0.14	
		Late flowering	4.68	3.82	0.11	
T2 (200 ppm)	June 6 2017	Early flowering	24.91	21.87	6.26	Temperature: 18.6 to 21.7°C Relative humidity: 19 % Wind speed: 2.1 km/h
		Seasonal	23.01	20.4	5.08	
		Late flowering	19.64	18.71	3.57	

2.2.4 Fruit drop monitoring

For the monitoring of fruit drop, fruits of marked spikelet on the clusters of the sample of palm trees were counted just prior and after the application of NAA treatments. Thereafter, regular counts were performed every six days on treated and untreated spikelet. These counts determined the number of fruits dropped and that of retained fruits on each spikelet, and this is in order to study the effect of each NAA treatment on fruit drop.

2.2.5 Statistical analysis of data

Data analysis of studied parameters, calculation of the means and graphs monitoring were carried out using Excel software. The analysis of variance (ANOVA) is performed using Minitab 16 statistical software and multiple comparison of means is carried out according to Tukey test.

3 Results and discussion

3.1 Fruit set

Fruit set per flowering phase is presented in Table 4. It shows that the peak period of fruit set for the three flowering phases is located between May 26 and June 8, 2017, when climatic conditions, including temperature (mean temperature during this period is 27.5 to 30.5 °C) and day length are favorable for fruit set of date palm in the region of study. Cohen et al. [7] also reported that fruit set occurs when the mean temperature is above 25 °C and low day/night temperatures such as 20/8 °C increase the rate of parthenocarpic fruits. Insufficient cold during the winter season negatively affects fruit set in date palm, and mild winter temperatures may be considered the main reason for poor flowering and low fruit set in date palm in the Tuhama region of Yemen, where winter temperatures are lower than those of the areas of date palm production worldwide [17]. Environmental conditions before, after or during flowering may also have an impact on fruit set [9].

The period between the pollination date and the peak of fruit set decreases with the increase of the mean temperature at the time of the peak. It is for 25 days at a mean temperature of 27.5 °C during the peak of fruit set in the early flowering phase and 18 to 19 days at a mean temperature of 30.5 °C during the peak of fruit set in the late flowering phase (Table 4). Sedra [18] also reported that the period between the pollination date and the peak of fruit set tends to decrease with the increase of the day mean temperature. The rate of fruit set also varies according to flowering phases and the peak of fruit set of these phases varies between 42 and 57% (Table 4). Several authors have also reported that the

climatic conditions (mainly the temperature and day length) of the fruit set period, which is a spring period, are the favorable conditions for fruit set of date palm [7, 13]. The climatic conditions of the pollination period, which is also a spring period, can significantly affect the fruit set in date palm [19, 20, 21]. Some other authors reported that fruit set in date palm also varies according to cultivar, ranging from 84 to 95% in four varieties of date palm in the Dera Ismail Khan region, Pakistan [22, 23]. The rate of fruit set in these varieties is higher than that of our found for 'Majhoul' date palm in Tafilalet area, Morocco, despite the high rate of fruit set of the pollination method used in our trials. This may be due to the variety itself, environmental conditions or cultural practices [9].

Table 4 Fruit set in manual thinning treatment and per flowering phase of 'Majhoul' date palm in the Tinejdad region, Tafilalet area

		Number of flowers per spikelet	Number of knotted flowers per spikelet	The peak of fruit set (%)	Date of the peak of fruit set
Flowering phase	Early flowering	36.06	20,64	57,26	May 26 2017
	Seasonal	32.44	17,81	54,93	June 2 2017
	Late flowering	26.52	11,08	41,81	June 8 2017
Manual thinning treatment (T0)		30,54	16,41	53,75	

3.2 Fruit drop

3.2.1 Fruit drop before the application of NAA treatments

Fruit drop before the application of NAA treatments is low. It began one month after pollination for the early flowering phase and one month to 34 days after pollination for the seasonal phase (Tables 1 and 5). Several authors have reported that like other fruit species, date palm undergoes two waves of fruit drop. The first occurs a few weeks after pollination, it is often caused by a lack of or incomplete pollination, and the second occurs at the end of the 'Kimri' stage [23, 24]. Fruit drop in date palms also varies according to varieties, depending on their adaptation to high temperatures during the period of fruit drop. Moreover, it appears that varieties that do not tolerate high temperatures during this period of fruit drop have a high rate of fruit drop due to disruption of the physiological cycle of their fruits [23, 25]. For the late flowering phase, we have not recorded any fruit drop probably because of the fruit set process, which is still in progress at this flowering phase (Table 5).

Table 5 Fruit drop in the manual thinning treatment and per flowering phase after the application of NAA treatments in 'Majhoul' date palm in the Tinejdad region, Tafilalet area

		Number of knotted fruits/spikelet	Number of dropped fruits/spikelet		Total number of dropped fruits/spikelet on May 8 2017	The rate of fruit drop on May 8 2017
			May 2 2017	May 8 2017		
Flowering phase	Early flowering	20,64	1,38	3,09	4,47	21,65
	Seasonal	17,81	-	2,41	2,41	13,53
	Late flowering	11,08	-	-	-	-
Manual thinning treatment (T0)		16,41	-	1,91	1,91	11,63

3.2.2 Fruit drop after the application of NAA treatments

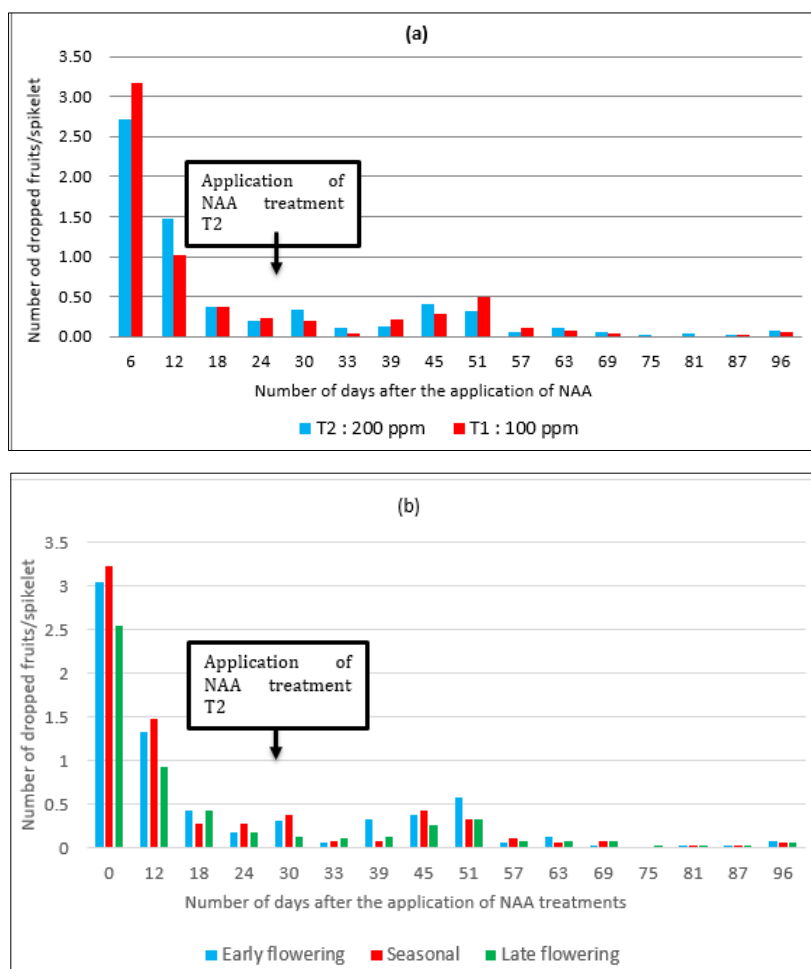


Figure 1 Evolution of the fruit drop per NAA treatment (a) (T1: 100 ppm and T2: 200 ppm) and per flowering phase (b) (early flowering, seasonal and late phases) of ‘Majhoul’ date palm in the Tinejdad region, Tafilalet area

The evolution of fruit drop per NAA treatment and flowering phase is presented in Figure 1. It shows that for NAA treatments, more than half of the total fruit drop is recorded one week after the application of T1 treatment (Figure 1a). Regarding the flowering phases and for the two weeks following T1 treatment, the number of dropped fruit in the seasonal flowering is higher than that of the early flowering and the late phase is the latest (Figure 1b). Whereas for the total number of dropped fruit per flowering phase, the early flowering is the first, followed by the seasonal phase and the late flowering is the latest (Table 6). For both flowering phases and NAA treatments, the number of dropped fruits after T1 treatment is higher than that of dropped fruits after T2 (Table 6). This is due partially to the best time chosen for the application of T1 and, on the other hand, to the period following the application of this treatment, which coincides with the first month after fruit set and which has favored the fruit set. T2 treatment, even with a double dose of that of T1, does not effect largely the fruit drop probably due to the large size of the fruits and which did not favor their drop.

Statistical analysis of data showed that for the number of dropped fruits per NAA treatment and flowering phase, the difference is significant ($p \leq 0.05$) between NAA treatments and between flowering phases. Whereas for the total number of dropped fruits per NAA treatment and flowering phase the difference is not significant ($p > 0.05$) between NAA treatments nor between flowering phases (Table 6). The higher rate of fruit drop in the late flowering phase is due to the lower number of knotted fruits and lower number of dropped fruits per spikelet in this flowering compared to other flowering phases (Table 6). Our results are in concordance with those of Abd El-Kader et al. [26] who reported that the applications of 40 and 50 ppm NAA on ‘Zaghloul’ date palm two weeks after pollination resulted in fruit drop of 38.12 and 40.53% respectively for both applications. This rate of fruit drop may be equivalent to manual thinning in date palm, as it may be sufficient to ensure sufficient fruit yield, with good quality dates. Our results on T2 treatment (200 ppm), which is a late application after pollination and which gave low fruit drop compared to T1 treatment are

consistent with those of Al-Qurashi et al. [27]. These later authors have shown that late applications of 100 and 150 ppm NAA on two varieties of date palm 40-70 days after pollination resulted in lower fruit drop (22.7-32.7%) due to NAA treatments, which were applied at a late stage of fruit development, when they reached a large size. Other authors indicated that manual thinning and chiseling did not reduce fruit drop in date palm [28, 29] and some other reported that application of 150 ppm Indol acetic acid (IAA) on two varieties of date palm in Dera Ismail Khan region, Pakistan, has reduced fruit drop in these varieties [30].

Table 6 Fruit set and number of dropped fruits per NAA treatment and flowering phase after the application of NAA treatments on 'Majhoul' date palm in the Tinejdad region, Tafilalet area

		Number of knotted fruits per spikelet	Number of dropped fruits per spikelet		Total number of dropped fruits per spikelet	The rate of fruit drop (%)
			After the application of T1 treatment	After the application of T2 treatment		
NAA treatment	T2 (200 ppm NAA)	17.93	5.19	1.21	6.40	35.69
	T1 (100 ppm NAA)	17.23	5.04	1.28	6.32	36.68
Flowering phase	Early flowering	20.64	7.47	1.33	8.80	42.63
	seasonal	17.81	6.60	0.93	7.53	42.27
	Late flowering	11.08	4.80	0.78	5.58	50.49

Regarding other fruit species, application of 20-60 ppm NAA resulted in 88-90 % fruit drop in mango [31]. While application of 10-30 ppm NAA on this species and other fruit species such as avocado and apple trees reduced fruit drop [32, 33, 34]. Non-severe manual thinning, with at least three fruits per branch, did not also reduce fruit drop in orange trees [35].

4 Conclusion

Fruit set in 'Majhoul' date palm in the area of study is important in May, when climatic conditions, mainly temperature and day length, are favorable for fruit set. The rate of fruit set is higher in the early flowering phase, followed by the seasonal flowering and the late phase is the latest. Fruit drop is low before the application of NAA treatments; it started one month after pollination in the early flowering and seasonal phases. After the application of NAA, fruit drop is important and more than half of the fruit drop is recorded one week after the application of T1 treatment. The number of dropped fruits after the application of T1 is higher than that of fruits dropped after the application of T2. This is due partially to the best time chosen for the application of T1 treatment and, on the other hand, to the period following this application, which coincides with the first month after fruit set, during which the fruits are still in the first stage of their development. T2 treatment, even with a double dose of T1, did not promote the fruit drop probably because of the large size of the fruits during this period of their development, and which did not promote the fruit drop. Trials comparing early and late NAA applications are required to confirm the effectiveness of early versus late NAA applications.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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