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Effect of chemical thinning on fruit growth and fruit quality of 'Majhoul' date palm at the end of the 'Khalal' stage

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Abstract

The aim of this research work was to study the effect of chemical thinning using NAA (Naphthalene acetic acid) and the manual thinning used by the farmer on the fruit growth and fruit quality of 'Majhoul' date palm at the end of the 'khalal' stage (color stage and fruit physiologically mature). Trials were carried out on an adult plantation in the Tinejdad region, Tafilalet area. Observations focused on monitoring the fruit growth of different flowering phases and fruit quality at the end of the 'khalal' stage. Obtained results showed that the evolution of the fruit size parameters is similar for all flowering phases and all thinning treatments and at the end of the 'khalal' stage there is no significant difference ($p > 0.05$) between flowering phases and between thinning treatments for these parameters. At the end of the 'khalal' stage, fruit length is between 4.8 and 4.9 cm and fruit mass is between 25.0 and 25.5 g. The content of sugar in the fruit is higher at the manual thinning treatment than at the NAA treatments, whereas the flowering phases have no effect on this parameter. The pH of the fruit juice is relatively similar for all thinning treatments and all flowering phases.

Keywords: Morocco; Tafilalet area; Majhoul date palm; NAA; flowering phase; fruit growth; Fruit quality

1. Introduction

The Middle East and North African countries are the largest producers of dates in the world with 9 million tons. Egypt is in the 1st place with 1.5 million tons and Iran is in the 2nd place with 1.2 million tons [1]. The current production in Morocco is for more than 102,000 tons, the occupied area is for more than 60,000 ha and the region of Draa-Tafilalet (located in the southeast part of the country) is the main production area in the country [2]. The variety diversity is rich and varied, it consists of more than 453 varieties and some of them are considered as first choice commercial varieties, mainly the varieties 'Majhoul', 'Bouffegous', 'Bouskri', 'Nejda', 'Jihel' [2].

Pollination is an important operation in the production of date palm and the quality of dates [3, 4, 5, 6] and the thinning practice is an operation which is used to achieve a balance between the production and the quality of dates and to avoid the phenomenon of alternating production. The reduction of clusters is a thinning practice, which is often carried out just after fruit set and the number of clusters kept by palm varies according to the plant age, the number of palms per palm and the water and mineral supply of the palm. Chiseling is also a thinning practice which consists in reducing the number of spikelet per cluster and/or the spikelet length [7, 8] and fruit thinning is an operation which consists of reducing the number of fruits per cluster when the fruits are still small [9]. Manual thinning, which is practiced by the farmers is an expensive operation because it requires skilled labor [7, 10, 11]. Thus, research must be directed towards alternatives which may replace the manual thinning such as chemical thinning using synthetic products like as NAA

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(Naphthalene acetic acid) which has been proven effective in date palm [7, 11, 12, 13, 14]. NAA has no insecticidal effect, making it harmless to the microphone [15]. Chemical thinning using NAA on date palm has been the subject of several research studies with the aim of improving fruit yield and quality [12, 13, 16, 17, 18]. Several authors have shown that applying NAA 20 to 30 days after pollination, at the 'hababouk' stage (immature fruits in the form of peas) improves fruit yield and quality of kept fruit [19, 20]. In apple tree, the application period of NAA is also determined based on fruit size after fruit set and the number of days after flowering [19, 20]. A temperature of 15 to 18 °C, over 80% relative humidity and not sunny time (because NAA is photodegradable), are the climatic conditions which are suitable for the application of NAA [21].

Samouni et al. [22] reported that removing 15, 30 or 45% fruit per cluster in 'Khalas' and 'Barhe' date palm improved fruit and pulp mass. Applying 50, 100, 150 and 200 ppm NAA on 'Barhee' and 'Shahl' date palm ten weeks after fruit set [23] or 100 and 300 ppm on the 'Succary' cv 30 days after pollination [24] increased fruit yield and fruit size. Arba et al. [15] indicated that Applying 150 + 300 ppm NAA and 250 + 500 ppm on 'Majhoul' date palm 30 and 60 days after pollination resulted two months later in a difference in the evolution of fruit size between thinning treatments. At the end of observations, which coincides with the beginning of the 'Rutab' stage (fruit ripening stage, soft fruit, and succulent texture) the difference between thinning treatments is significant. Elladi and Ouachouo [25] reported that NAA applications they used on 'Majhoul' date palm (150 + 300 ppm and 250 + 500 ppm 30 and 60 days after pollination) decreased the content of sugar in the fruit compared to untreated plants and manual thinning treatment. Applying 150 and 200 ppm NAA on 'Succary' date palm five weeks after pollination decreased the sugar content in the date [26]. El-Kosary [27] indicated that an application of 75 ppm of Cytophex (CPU, 2-chloro-4-oridyl phenyl) on 'Sumary' and 'Zaghloul' date palm four weeks after pollination increased fruit size. According to Acourene et al. [28], a pH above 6 is a good chemical character for 'Majhoul' dates because this value of pH is a good biochemical criterion for their postharvest conservation.

Chemical thinning has been the subject of several research studies in developed countries since the thirties of the last cycle. Research studies carried out focused on the evaluation of the thinning qualities of different products, the period of their application, used concentrations and the mode of their action. The chemical thinning is not yet well mastered in Morocco and the benefits of this operation are often unknown [29]. The aim of our research work is to study the effect of different concentrations of NAA after pollination on fruit growth of 'Majhoul' date palm and fruit quality at the end of the 'khalal' stage.

2. Material and methods

2.1. The site of trials

Trials are carried out on an eight-year old plantation of 'Majhoul' date palm in the Tinejdad region, Tafilalet area: latitude 31° 32' N, longitude 4° 52' W, altitude 1062 m. The mean temperature in the site of trials can reach 40 °C in July and 2 °C in January. The relative humidity varies between 54 % in January and 16 % in July and the annual rainfall is for 105 mm. The soil of the parcel of trials has a sandy-silty texture with 55% sand, 31% silt and 12% clay, and 6% limestone. It is low in organic matter (0.21%) and the pH is for 6.95. The planting density in the parcel of trials is 6 x 6 m (277 palms per ha) and the palms used in the study are without any signs of serious diseases such as 'Bayoud' and mineral deficiencies. The irrigation system used in the parcel of trials is drip irrigation with two ramps of drippers per row of plantation and two drippers per palm tree (one dripper per ramp of drippers). The organic manure is brought once a year, in May and the amount provided is 150 kg per palm tree, and the mineral fertilization is provided twice a year, in February and June. Watering and fertilizing programs used in the parcel of trials are presented in Table 1.

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

Fertilizing program				**Watering program**	
Fertilizers used	Principal constituants	Amount brought per palm tree on February	Amount brought per palm tree on June	Watering dose per palm tree and frequency of the apports	Periods of the apports
Composed fertilizears	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 kg K_2O and 0.06 kg MgO)	1 kg (0.14 kg N, 0.07 kg P_2O_5, 0.21 kg K_2O and 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 liters per palm tree per 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	-	1 kg (0.13 kg N, 0.46 kg K_2O)	400 to 600 liters per palm tree per 2 days	May to November
DAP Diammonium-triphosphate	18 % N, 46 % P_2O_5	1 kg (0.18 kg N, 0.46 kg P_2O_5)	-		

2.2. Adopted experimental design and studied flowering phases

The experimental design adopted is a split plot with two factors (flowering phase and thinning treatment), three blocks, three thinning treatments per block and three flowering phases per thinning treatment, a total of 27 experimental units and each unit is composed of two clusters per flowering phase. The blocks are arranged perpendicular to the direction of the prevailing winds gradient. The flowering phases studied are: early, seasonal and late flowering phases. They were determined according to Arba et al. [30]. Pollination of palm trees in the parcel of trials is carried out manually by placing 3 to 5 spikelet of mature male inflorescence in the middle of the female inflorescence and ligating it with a lacing of leaflets. It is carried out with the pollen of the same male palm tree 3 to 7 days after the opening of the female spathes and the male inflorescences were harvested 3 to 5 days after the opening of the male spathes. The pollination was carried out on 1 April 2017 for the early flowering, between 7 and 12 April for the seasonal flowering and from 19 to 20 April for the late flowering.

2.3. Limitation of clusters and fruit thinning

The limitation of clusters or the reduction of the number of clusters per palm is carried out on May 7, 2017 by cutting some clusters during an early stage of fruit growth after fruit set and the mean number of clusters kept per palm tree is 7. Fruit thinning is carried out manually, by removing some fruits per diet in order to promote the development of kept fruits on the cluster . It is carried out on May 16 2017 for the early flowering phase, on May 22 for the seasonal flowering phase and on June 3 2017 for the late flowering phase. The percentage of removed fruits per cluster depends on the clusters fruit load; it was 55% for the early flowering , 48% for the seasonal phase and 35% for the late flowering. NAA is the product used in the fruit chemical thinning . It is applied in two concentrations: 100 ppm and 200 ppm and in order to facilitate its assimilation during its applying, a non-ionic surfactant-type alcohol wetting agent was added to the porridge with a concentration of 1%. NAA treatments are carried out by spraying the porridge on the clusters to the point of dew. They are applied during the end of day, when the air is fresh and the sun is less intense, to avoid degradation of the product by sunlight and rapid drying of the porridge. Climatic conditions during the application of NAA, used concentrations of NAA and the dimensions of the fruits during the time of application of NAA are presented in Table 2.

Table 2 Climatic conditions at the time of application of NAA, NAA treatments used, application dates of NAA and fruit size of 'Majhoul' date palm during the application of NAA in the Tinejdad region, Tafilalet area, Morocco

NAA treatments used	Application date of NAA	Flowering phase	Fruit dimensions during the application of NAA		Climatic conditions during the application of NAA
			Fruit length (mm)	Fruit diamètre (mm)	
T1 (100 ppm)	May 09 2017	Early	5.69	4.73	Temperature: 21.6 à 23.5 °C Air relative humidity: 18% Wind speed: 3.4 km/h
		Seasonal	5.23	4.35	
		Late	4.68	3.82	
T2 (200 ppm)	June 10 2017	Early	24.91	21.87	Temperature: 18.6 à 21.7 °C Air relative humidity: 19% Wind speed: 2.1 km/h
		Seasonal	23.01	20.4	
		Late	19.64	18.71	

2.4. Fruit growth monitoring and study of fruit quality at the end of the 'khalal' stage

To study the effect of NAA treatments and flowering phases on fruit growth and fruit quality at the end of the 'khalal' stage we followed the fruit growth at intervals during the fruit development period (from May 9 to August 22, 2017) and we studied fruit quality at the end of the 'khalal' stage. Fruit growth monitoring and the study of fruit quality are carried out on a sample of 6 fruits per experimental unit, 54 fruits per thinning treatment or flowering phase and per date of observation which corresponds to a fruit development or fruit growth stage . Fruit samples were taken during the following dates: May 09 2017, June 03 2017, June 23 2017, July 13 2017, August 02 2017 and August 22 2017. Fruit growth focused on the parameters of fruit dimensions (fruit length and diameter), fruit mass and size and fruit quality is focused on fruit size and some organoleptic parameters of the fruit at the end of the 'khalal' stage. Fruit dimensions are measured with a caliper, fruit, pulp and seed mass are measured using an electric scale with a precision of 0.01 g, and fruit size is determined using a graduated test tube of 10, 100 and 250 ml. The pulp rate in the fruit is determined according to the following formula:

$$\text{Pulp rate (\%)} = \text{Pulp mass} / \text{Total fruit mass} \times 100$$

Regarding the organoleptic parameters of the fruit, fruit dry mass is obtained by drying fruits without their seeds and chalices in a drying oven at 70 °C for 48 hours. For the determination of the pH and the content of sugar in the fruit , the pulp of the sample of fruits was finely ground with twice of its volume in distilled water and the filtrate is then centrifuged in a centrifuge to separate the liquid phase from the solid phase and to extract the juice from the fruit. The content of sugar in the fruit or degree Brix is determined using a refractometer and the pH of the fruit juice is determined using a pH meter.

2.5. Statistical analysis of data

Data analysis of studied parameters, calculation of the means and the design of graphics are carried out using the software Excel. The ANOVA (analysis of variance) is performed using Minitab 16 statistical software and the multiple comparison of means is carried out using the Tukey test.

3. Results and discussion

3.1. Fruit growth evolution

3.1.1. Fruit growth evolution before the application of NAA

The evolution of the fruit growth parameters (fruit size, dimensions and fruit mass) by flowering phase and before the application of NAA is presented in Figure 1. It shows that the evolution of the growth parameters is similar for all the flowering phases, but the difference is significant ($p > 0.05$) between these flowering phases, with often a slight superiority of the early flowering phase compared to the other phases. This difference disappears at the end of the period of fruit growth (Figure 1a, b, c and d). Our results are in agreement with those of Arba et al. [15, 30] who reported that the flowering phases affect fruit size, dimensions, and fruit mass in 'Majhoul' date palm during the fruit

development period, and at the end of this period, the evolution of these parameters is similar for the all flowering phases.

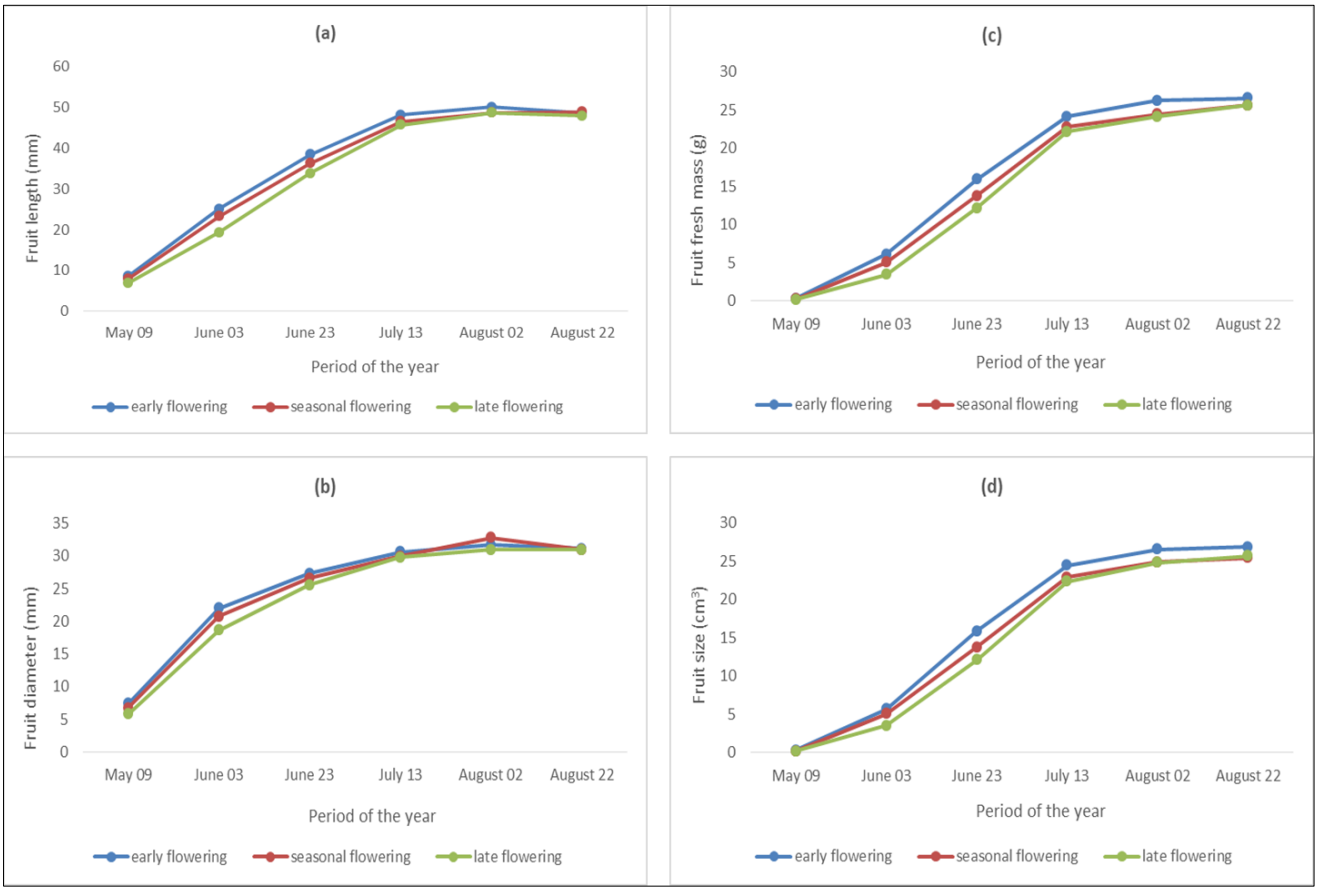

Figure 1 Evolution of fruit length (a) and diameter (b), fruit fresh mass (c) and size (d) of 'Majhoul' date palm according to the flowering phases: early flowering, seasonal and late phase and before the application of NAA in the Tinejdad region, Tafilalet area, Morocco

3.2. Fruit growth evolution after the application of NAA

After the application of NAA, the evolution of fruit length and diameter is almost similar for all the thinning treatments (including manual thinning) during the fruit development period where these thinning treatments are statistically not different ($p > 0.05$). The evolution of fruit and pulp fresh mass and fruit size after the application of NAA is presented in Figure 2. It shows that except for August 02 2017 where the difference is significant ($p \leq 0.01$) between thinning treatments for these parameters (due to their decrease in T2 NAA treatment), the evolution of these fruit parameters is similar for all the thinning treatments (Figure 2a, b and c). Moreover, the difference is not significant ($p > 0.05$) between them for the rest of the fruit development period. During the first period of the evolution of the fruit parameters, which extends from May 09 to June 03 2017, the increase in fruit size is relatively low, and during the second period of this evolution, which extends from June 03 to August 02, 2017, the increase in fruit size is higher for NAA T1 treatment and manual thinning treatment. This second period in the evolution of fruit growth coincides with the rapid period of fruit growth. During the third period of this evolution, which extends from August 02 to 22 2017, fruit size has experienced a remarkable slowdown, even stable towards the end of fruit growth for NAA T1 treatment and manual thinning.

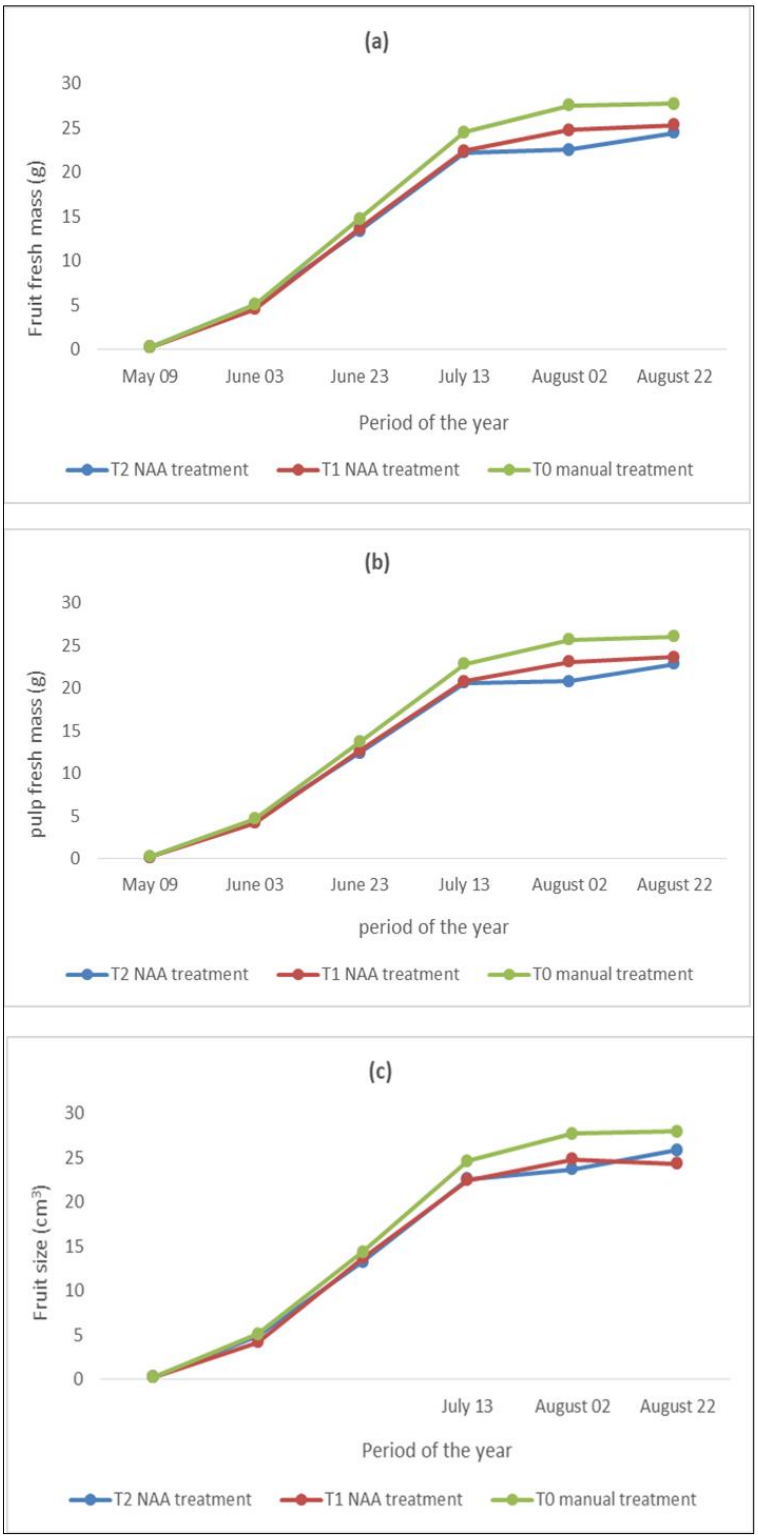

Figure 2 Evolution of the fruit and pulp fresh mass (a and b) and fruit size (c) of 'Majhoul' date palm according to manual thinning treatment (T0) and NAA thinning treatments T1 (100 ppm NAA) and T2 (200 ppm) and for all the flowering phases (early, seasonal and late flowering) in the Tinejdad region, Tafilalet area

Figure 2 also shows that the fruit size parameters are positively correlated between them and that the pulp ratio is always more than 92% of the fruit mass for all the thinning treatments and all the fruit development stages. What indicates that applying NAA does not affect largely the pulp growth (Figure 2b). The pulp ratio is an important parameter of quality, which is used in the classification of dates and in the selection grid of date palm clones and cultivars based on the quality of dates. Regarding the interaction between the factors thinning treatments and flowering

phases, statistical analysis of data showed that, except for June 3 2017, where the interaction between the two factors is positive for the parameters fruit mass and diameter, there is no interaction between the two factors for the other stages of fruit development.

3.3. Fruit quality at the end of the 'khalal' stage

3.3.1. Fruit quality before the application of NAA

At the end of the 'khalal' stage, the fruit size is almost similar for all flowering phases. Fruit length varies between 4.7 and 4.8 cm, fruit diameter is 3.0 to 3.1 cm, and fruit mass varies between 25.63 and 26.55 g. According to Acourene et al. [28], the fruits of 'Majhoul' date palm at the end of the 'khalal' stage can be classified in large size for all the flowering phases (4 cm for fruit length and 8 g for fruit mass) (Figure 1a and c). Moreover, according to MAPM [31] commercial standards, the fruits of all the flowering phases at the end of the 'khalal' stage can be classified as extra commercial size (fruit mass > 19.5 g) (Figure 1c). This indicates that the fruits of different flowering phases can reach the same size at the end of the growth period if the clusters fruit load is well balanced and reasoned. Such result is very important and so useful for the efficient management of the production by choosing the flowering phase, which could facilitate the management practices such as fruit thinning and other practices used in the improvement of fruit quality. Pulp mass at the end of the 'khalal' stage is relatively similar for all the flowering phases. It is for 93.84 g for the early flowering phase, 93.51 g for the seasonal phase and 93.67 g for the late flowering. It is an important parameter of quality in the classification of dates.

The pH of the fruit juice and the content of sugar in the fruit are also relatively similar for all the flowering phases. The content of sugar in the fruit is 11.23 °Brix for the early flowering, 10.66 for the seasonal phase and 10.26 for the late flowering and the pH of the fruit juice is 5.63 for the early flowering, 5.60 for the seasonal flowering and 5.59 for the late phase. These pH values are below 6 which may be the highest pH value for 'Majhoul' date palm [32] and can be a good chemical character for date postharvest conservation [28]. Our results are in disagreement with those of Elladi and Ouachouo [25] who reported that the flowering phases affect significantly the pH of juice and the content of sugar in the fruit and that these parameters are higher in the early flowering phase than in the other phases. Probably because of the ripening period which is later in their case where fruits are at the 'Rutab' stage, which comes after the 'khalal' stage. On the other hand, the fruit load of palm trees, which is higher in their case where the palms are more loaded in clusters and the ripening is more important than in our case where the ripening is still slow and weak because the fruits are still in the 'khalal' stage.

The evolution of fruit dry mass and seed mass during the fruit development period according to flowering phases and before the application of NAA is presented in Figure 3. It shows that for seed mass and except for July 13, 2017 where the difference is significant ($p \leq 0.01$) between the flowering phases, the difference is not significant ($p > 0.5$) between these flowering phases for the other stages of fruit development, as this difference will disappear at the end of the 'khalal' stage (Figure 3a). The evolution of fruit dry mass is similar for all the flowering phases and fruit dry mass of the early flowering is always higher than that of the other flowering phases (Figure 3b). During the first period of fruit growth, which extends from May 9 to June 23, 2017, the difference between flowering phases for fruit dry mass is not significant ($p > 0.05$). Therefore, for the second period of fruit growth, which extends from July 13 to August 22 2017, the difference between flowering phases for fruit dry mass is significant ($p \leq 0.05$) (Figure 3b). Elladi and Ouachouo [25] also reported that in 'Majhoul' date palm, the difference between flowering phases for fruit dry mass is significant during the fruit development period.

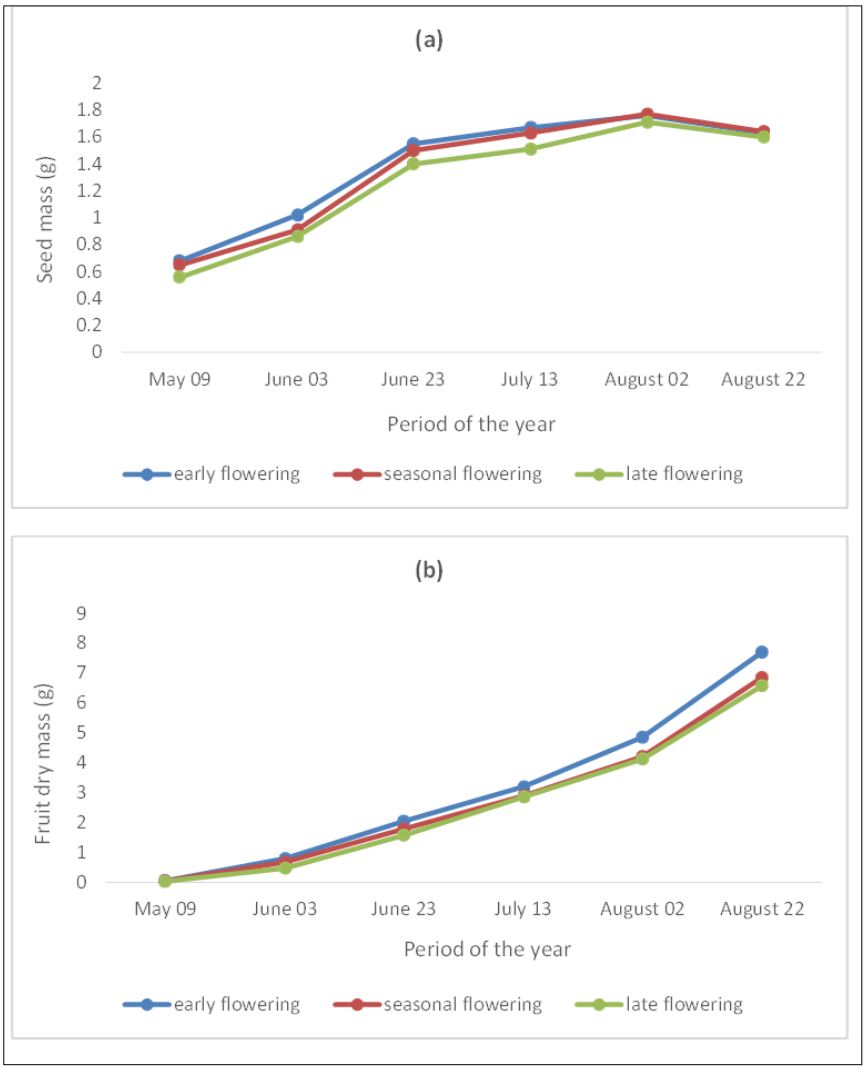

Figure 3 Evolution of the seed mass (a) and fruit dry mass (b) of 'Majhoul' date palm according to the flowering phases: early, seasonal and late flowering and before the application of NAA in the Tinejdad region, Tafilalet area

3.3.2. Fruit quality after the application of NAA

At the end of the 'khalal' stage, fruit dimensions are similar for all thinning treatments; fruit length varies between 4.7 and 4.8 cm and fruit diameter varies from 3.0 to 3.1 cm. Therefore, fruit mass is higher in manual thinning (27.68 g) than in NAA treatments (24.43 g for T2 and 25.28 for T1). The content of sugar in the fruit is also higher in manual thinning (12.88 °Brix) than in NAA treatments (9.67 °Brix for T1 and 9.60 for T2) and statistical analysis of data showed that the difference is significant ($p \leq 0.05$) between the thinning treatments. The pH of the fruit juice is relatively similar for all the thinning treatments. It is for 5.63 for manual thinning and 5.58 and 5.61 for T1 and T2 NAA treatments, and statistical analysis of data showed that the difference is not significant ($p > 0.05$) between the thinning treatments. Elladi and Ouachouo [25] also reported that the thinning treatments they used on 'Majhoul' date palm affect significantly the content of sugar in the fruit. The highest content was obtained with the untreated control and the manual thinning used by the farmer, and NAA treatments are the last, probably because the application of NAA has reduced the content of sugar in the fruit. Several other authors also reported that the application of 150 and 200 ppm NAA on 'Succary' date palm seven weeks after pollination [26] or on 'Barhe' and 'Shahl' date palm ten weeks after fruit set [23] leaded to a decrease in the content of sugar in the fruit. However, some other authors indicated that applying NAA on some varieties of date palm provoked an increase in the content of sugar in the fruit. An application of 100 ppm NAA on 'Barhe' date palm ten days and seven weeks after pollination [33] or 80 and 100 ppm on 'Barhe' and 'Succary' cultivars fifteen weeks after pollination [19, 34] leaded to an increase in the content of sugar in the fruit of these varieties. The differences in the results of cited authors may be due to the ripening stage of studied varieties and management practices used in each case. The two main factors are the water and mineral supply of plants, and the environmental conditions prevailing in the growing site of date palm in each case of study . Regarding the pH of the fruit juiice, Elladi and Ouachouo [25]

indicated that the thinning treatments they used on 'Majhoul' date palm affect significantly the pH of the fruit juice, Probably because of the ripening stage they studied ('Rutab' stage) and which follows the 'khalal' stage, and the NAA treatments they used and which differ from the ours.

The evolution of fruit dry mass and seed mass during fruit growth and after applying NAA is presented in Figure 4. It shows that seed mass is low for all the thinning treatments (Figure 4a) and even there are differences between these treatments during the period of fruit growth, these differences disappear at the end of the 'khalal' stage (Figure 4a). Low seed mass is a good criterion, which is sought in the varietal selection of good quality dates. Figure 4b shows that fruit dry mass of the control is often higher than that of NAA treatments and that the application of NAA does not affect the fruit dry mass. Elladi and Ouachouo [25] also reported that the NAA treatments they used on 'Majhoul' date palm (150 + 300 ppm and 250 + 500 ppm 30 and 60 days after pollination) decreased fruit dry mass compared to the control treated with clear water and manual thinning used by the farmer.

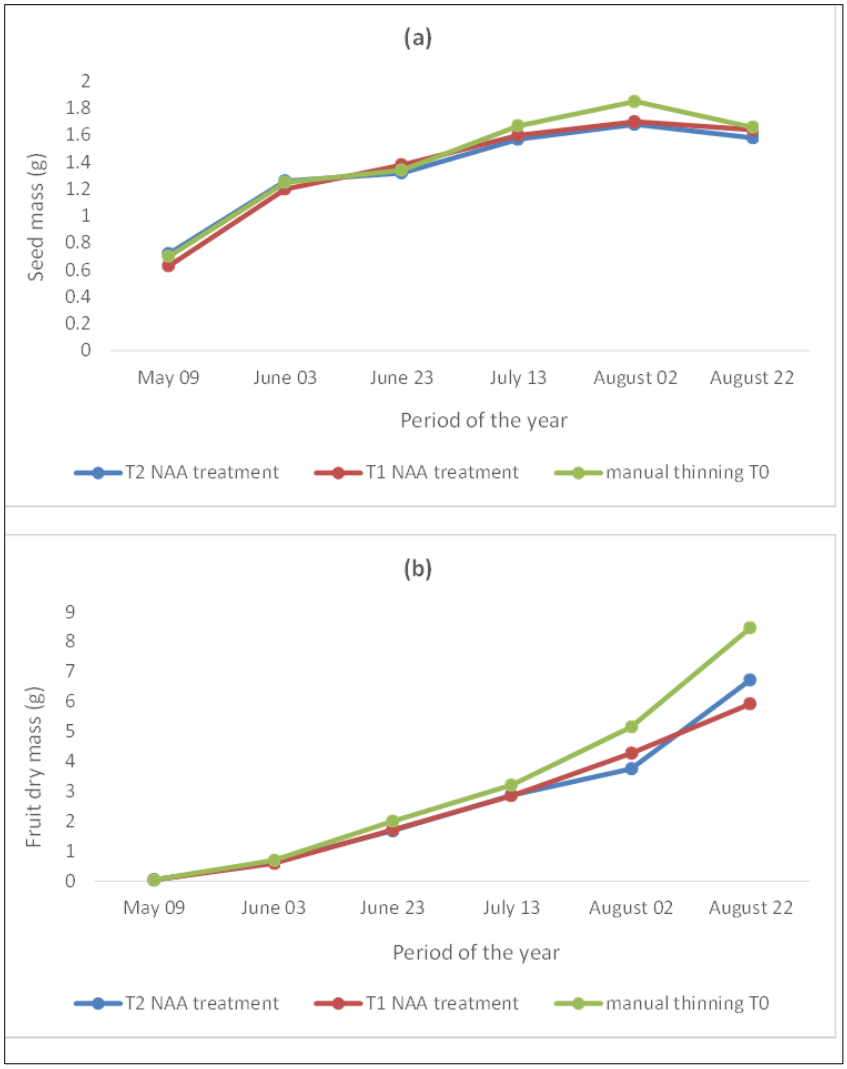

Figure 4 Evolution of seed mass (a) and fruit dry mass (b) of 'Majhoul' date palm during the period of fruit growth and according to the thinning treatments T0, T1 and T2 in the Tinejdad region, Tafilalet area

4. Conclusion

The evolution of fruit growth parameters is similar for all the flowering phases and all thinning treatments during the fruit development period, and at the end of the 'khalal' stage, fruit size is almost similar for all these treatments and flowering phases. At the end of this stage, the pH of the fruit juice is also similar for all the flowering phases and thinning treatments. Thinning treatments affect significantly the content of sugar in the fruit because the application of NAA decreased this parameter in the fruit. However, the flowering phases do not affect the content of sugar in the fruit probably because the clusters are less loaded in fruits in all the flowering phases. During the fruit development period,

fruit dry mass is always higher in the early flowering phase than in the other phases because during the fruit development period, fruit size of this early phase is always higher than that of the other phases . At the end of the 'khalal' stage, fruit dry mass of the manual thinning is higher than that of NAA treatments probably because fruit size of this thinning treatment becomes higher than that of NAA treatments at the end of this stage. While, for seed mass it is low during the fruit development period for all thinning treatments and all flowering phases, and at the end of the 'khalal' stage it is similar for these thinning treatments and flowering phases.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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