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FRUIT GROWTH PATTERN IN DATE PALM (*Phoenix dactylifera)* 'SUKKARY' AND 'KHLASS' VARIETIES

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ABSTRACT

The growth physiology of date palm *(Phoenix dactylifera*) 'Sukkary' and 'Khlass' was determined. This research sought to study the fruit growth pattern of these two varieties and to elucidate the different growth phases of the fruits to better manage thinning, water and nutrient supply of the crop. These were done using the following fruit parameters: weight, volume, length and width. When regressed against fruit weight, all other mentioned parameters had a high determination coefficient. The fruit patterns of bunch cut thinning method were compared with non-thinned fruits and surveyed for an alternative to hand thinning in order to improve fruit size. It was suggested that bunch cutting at the time of pollination and keeping of 12 fruits per spikelet are better alternatives to hand thinning. These alternative methods improved better fruit size in 'Sukkary' (17.4 g) compared to hand thinned fruits (16.2 g) and to non-thinned fruits (13.7g).

Key words: bunch, curve, date palm, fruit, thinning.

INTRODUCTION

Date palm (*Phoenix dactylifera*) is an agricultural crop that has a long history in human civilization. It is religiously of great importance in Christianity and Islam. In Islamic countries, dates are considered as traditional fruit and are always included in meals for sacred events whilst in Christianity and Judaism, the leaves of date palm are used for religious celebration (Musselman 2007). Dates are staple food in the Middle East and are also widely distributed and cultivated in northern Africa and Southwest Asia. In Southeast Asia, on the other hand, date palm is popularly utilized as a good source of bioenergy (Baker and Couvreur 2011). Moreover, the marketing potential of date palm fruits is favorably considered in European and Asian countries where Islamic Southeast Asian countries like Malaysia has been long been importing date fruits (FAO 2004).

Earlier studies have shown that constituents of dates act as potent anti-tumor, anti-inflammatory and antioxidant. It could potentially provide a suitable alternative to alleviate various diseases. (Rahmani et al. 2014). Dates fruit is composed mainly of carbohydrates. The sugars in dates are easily digested and can immediately be transported to the blood after consumption and can quickly be metabolized to release energy for various cell activities (Amanat et al. 2012). It is also rich in

dietary fibers, some essential vitamins, and minerals and a variety of phytochemicals (*e.g*., phenolics, carotenoids, anthocyanins, procyanidins, and flavonoids). Moreover, dates are also abundant with insoluble fibers, which are important for gastrointestinal health (Jasim et al. 2013).

In 2017, the global production of dates increased to about 8.32 million tons from 7.53 million tons in 2010 (FAO 2017). Number of studies have shown the significance of understanding the strategic management for dates and also to identify the adequate time of fertilization and other cultural practices for better fruit yield and quality. The identification of phenological stages of a crop in a given locality is of prime importance in management (Tajero et al. 2010) and modeling of fruit growth (Mechlia and Carroll 1999). This research sought to study the fruit growth pattern of two date palm (*Phoenix dactylifera*) varieties 'Sukkary' and 'Khlass' and to elucidate the different growth phases of the fruits to better manage thinning, water and nutrient supply of the crop.

METHODS AND MATERIALS

The study was done in Nafeesa farm of Yousef Abdul Latif and Sons Agriculture (YALA) Company in Shihya, Saudi Arabia in 2018. Six-year-old trees of 'Sukkary' and 'Khlass' varieties of date palm were used in the experiment. Two methods were used to investigate the growth of date fruits: destructive method based on the weight and volume of fruits and non-destructive method based on length and width of fruits.

The destructive method was carried out using a top load balance to measure fruit fresh weight while the water displacement was measured through a graduated cylinder to determine the fruit volume. These were done in nine (9) bunches of dates that were opened, pollinated and tagged at the same time. Every three days, 3 strands of fruits were randomly collected from 3 bunches and were measured accordingly. The non-destructive method, on the other hand, was carried out using a digital caliper to measure the size (width and the length) of the fruits every 3 days after pollination without removing from its strand. This was done by randomly selecting three trees of each variety and were tagged accordingly. The measurements (destructive and non-destructive) were continued until fruit maturation and harvest. For the destructive method of measurement at fruit maturation, bunches and strands were thinned at the time of pollination by cutting the strands and kept 12 fruits per strand.

Moreover, to evaluate bunch cut as an alternative method of thinning to hand thinning, three series of homogeneous ten-year-old Sukkary trees were selected. Each series was composed of 20 trees. The experiment was conducted in a randomized block design with 3 treatments: hand thinned trees, bunch cut at 12 fruits and the unthinned trees as control. In bunch cut at 12 fruits, the spikelets of the bunch are cut after keeping 12 fruits while the rest were removed.

RESULTS AND DISCUSSION

Growth pattern and duration of phases. Both of the fruit growth patterns of 'Sukkary' and 'Khlass' followed a sigmoid growth curve which could be divided into 5 main phases. The Phase I, characterized by slow growth, is the phase where cell division occurred and lasted 32 days in 'Sukkary' while 30 days in 'Khlass'. It was followed by the exponential phase (Phase II) where cells elongation and water accumulation started. Cell growth reached its maximum (Phase III), and diminished progressively (Phase IV) until it became stationary (Phase V). This was followed by fruit maturation where weight gradually decreased.

Daily growth rate and growth phases. Daily increase of fruit size in 'Sukkary' (Fig. 1. a) and 'Khlass' (Fig. 1. b) and their growth rate (Fig. 2.) were recorded.

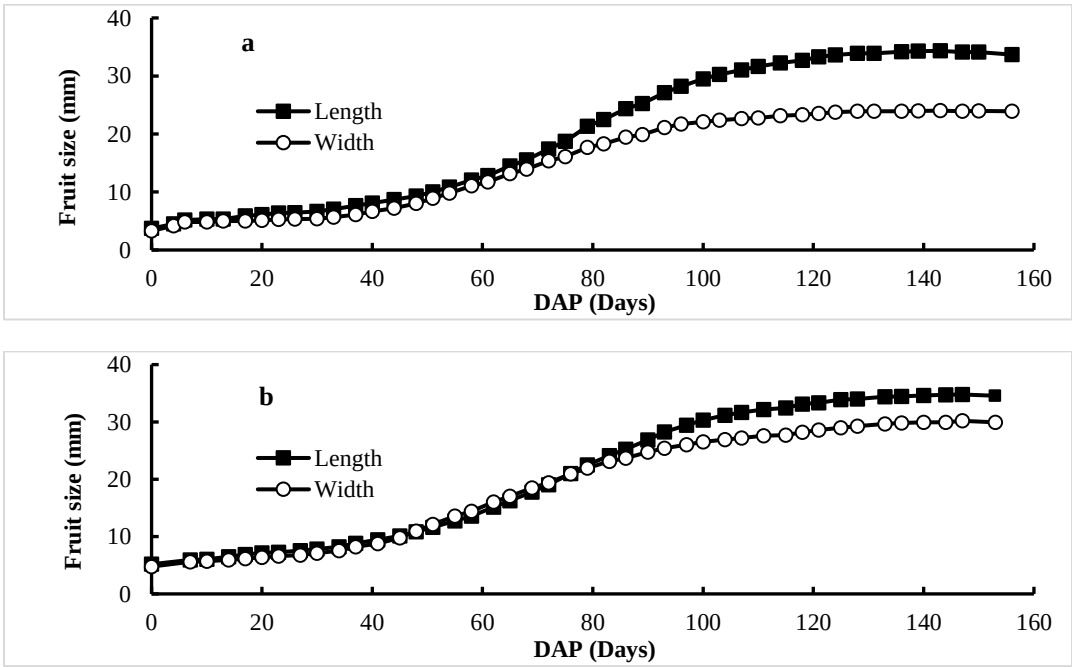

Fig. 1. Fruit growth of Khlass (a) and Sukkary (b) based on fruit size from day of pollination to harvest.

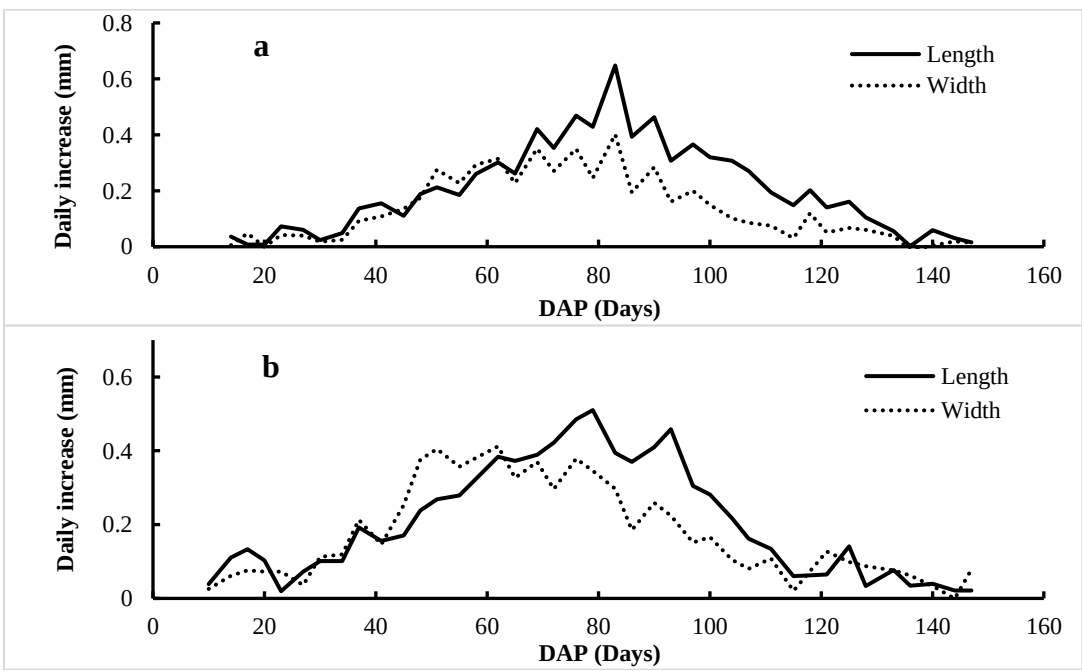

Fig. 2. Daily fruit growth of Khlass (a) and Sukkary (b) from day of pollination to harvest.

Lag Phase. A slow increase in fruit size (length and width) of 'Khlass' was observed until 37 DAP while in 'Sukkary' fruit width was in lag phase until 30 DAP and until 34 DAP for fruit length. Moreover, there is a daily growth rate of less than 0.1 mm observed in both varieties of date fruits.

Exponential phase. A significant increase in daily growth rate was observed in both date fruit varieties. 'Khlass' between 37 DAP and 58 DAP had a significant increase in fruit width and 62 DAP for fruit length. As for 'Sukkary', significantly expanded in fruit width until 48 DAP and increased in fruit length until 62 DAP.

Linear phase. Daily growth rate for fruit became linear at approximately more than 0.3 mm. Linear growth was observed until 83 DAP for 'Khlass' variety. Until 83 DAP, 'Sukkary' had a linear increase in width whilst until 79 DAP for its fruit length.

Diminishing growth phase. At this growth phase, the daily fruit growth rate was at approximately 0.1 mm. There was observed decrease in fruit length and fruit width on 'Khlass' at 104 DAP and 128 DAP, respectively. 'Sukkary', on the other hand, had the same decrease in fruit size at 104 DAP (width) and 111 DAP (length).

Stationary phase. Fruit growth was slow with daily growth rate of less than 0.1 mm. Increase in fruit size became stationary at 104 DAP and 128 DAP for width and length of 'Khlass', respectively. For 'Sukkary', increases in width and length were stagnant at 104 DAP and 111 DAP, respectively, growth for both varieties ended at 147 DAP and developed into mature stage or Tamar (10-30% moisture).

Earlier reports showed that date fruit at Kimri stage (1–30 DAP), are hard and green in color due to high cell multiplication. In the Khalal stage (31–90 DAP), cells further multiply and expand resulting to starch accumulation and color development. At Biser stage (91–120 DAP) cell expansion continues to occur. The fruit color changes from green to yellow or red and fruit taste has little to no sweetness. At Rutab stage (121–150 DAP), the color gradually changes from yellow or red to light to dark brown or black. Sugars, at this state, continued to accumulate. The last stage represents the Tamar stage (151–180 DAP), where fruit have ripened, and accumulated sugars are converted into glucose and fructose (Yin et al. 2012; Gribaa et al. 2013).

Linear regression of fruit weight to fruit size and volume. In this study, a non-destructive approach of fruit size measurement was employed; however, it was time-consuming as it was done in the field. On the other hand, a destructive method of measurement was done to determine the weight and volume of the fruit. This approach was found to be a good method to use in laboratories which could be more work efficient and accurate. Thus, the correlation of the physical properties based on the measurement methods was determined to identify a more advantageous approach to be used in the future.

There was a significant positive relationship between fruit weight and fruit volume for both Sukkary and Khlass ($R^2 = 0.9809$ in Sukkary and $R^2 = 0.9908$ in Khlass). Also there were the same positive correlation between fruit weight and fruit width ($R^2 = 0.9861$ in Sukkary and $R^2 = 0.9481$ in Khlass) or fruit length ($R^2 = 0.9891$ in Sukkary and $R^2 = 0.9832$ in Khlass) (Fig. 3, Fig. 4) .Therefore, fruit volume or fruit width or fruit length could be used to assess fruit size. This agrees with the findings reported by Goffinet et al. (1995) in apple using fruit weight or fruit diameter with a correlation coefficient from 0.89 to 0.99. Based on these findings, it is suggested that the destructive method of measurement is a more efficient approach than that of the non-destructive one.

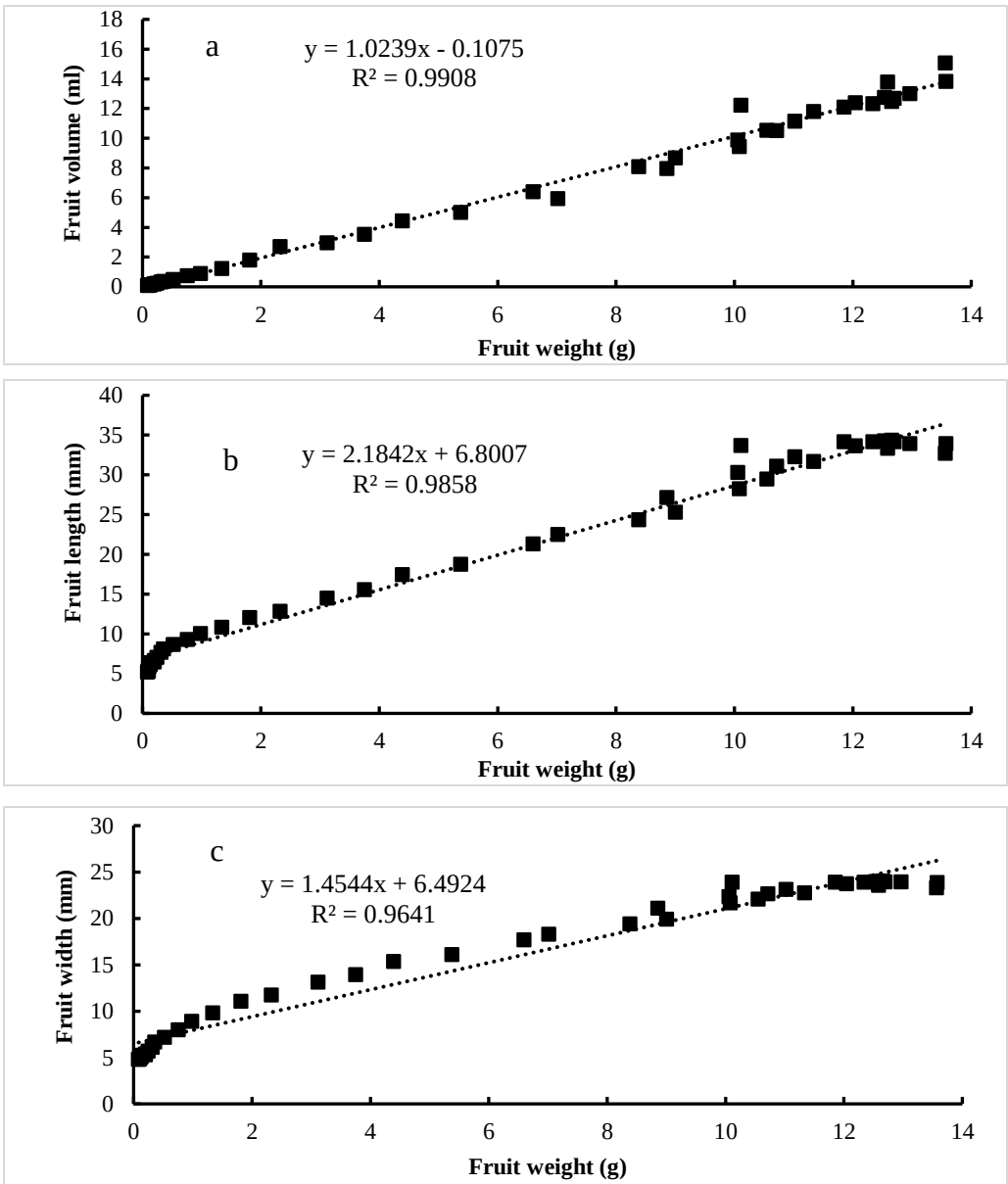

Fig. 3. Correlation of fruit weight between fruit volume (a) , width (b) and length (c) in 'Khlass'.

The relationship between fruit shape and weight in different species have been studied by various researchers. High determination coefficient between the physical properties of fruits has been found in gumbo (Akar and Aydin 2005) and orange (Tabatabaeefar et al. 2000). Among these physical properties, there is a high correlation between mass and volume of the tubers in potatoes (Tabatabaeefar 2002). Moreover, a weight-size correlation model has been developed for apples allowing the estimation of volume for a known density of the fruit (Tabatabaeefar and Rajabipour 2005). Khoshnam et al. (2007) developed an equation to determine the mass of pomegranates using the function of the minor diameter. Beyer et al. (2002) also developed a method to analyze the fruit shape of sweet cherry based on the correlation of digital images of fruits at ripening stage.

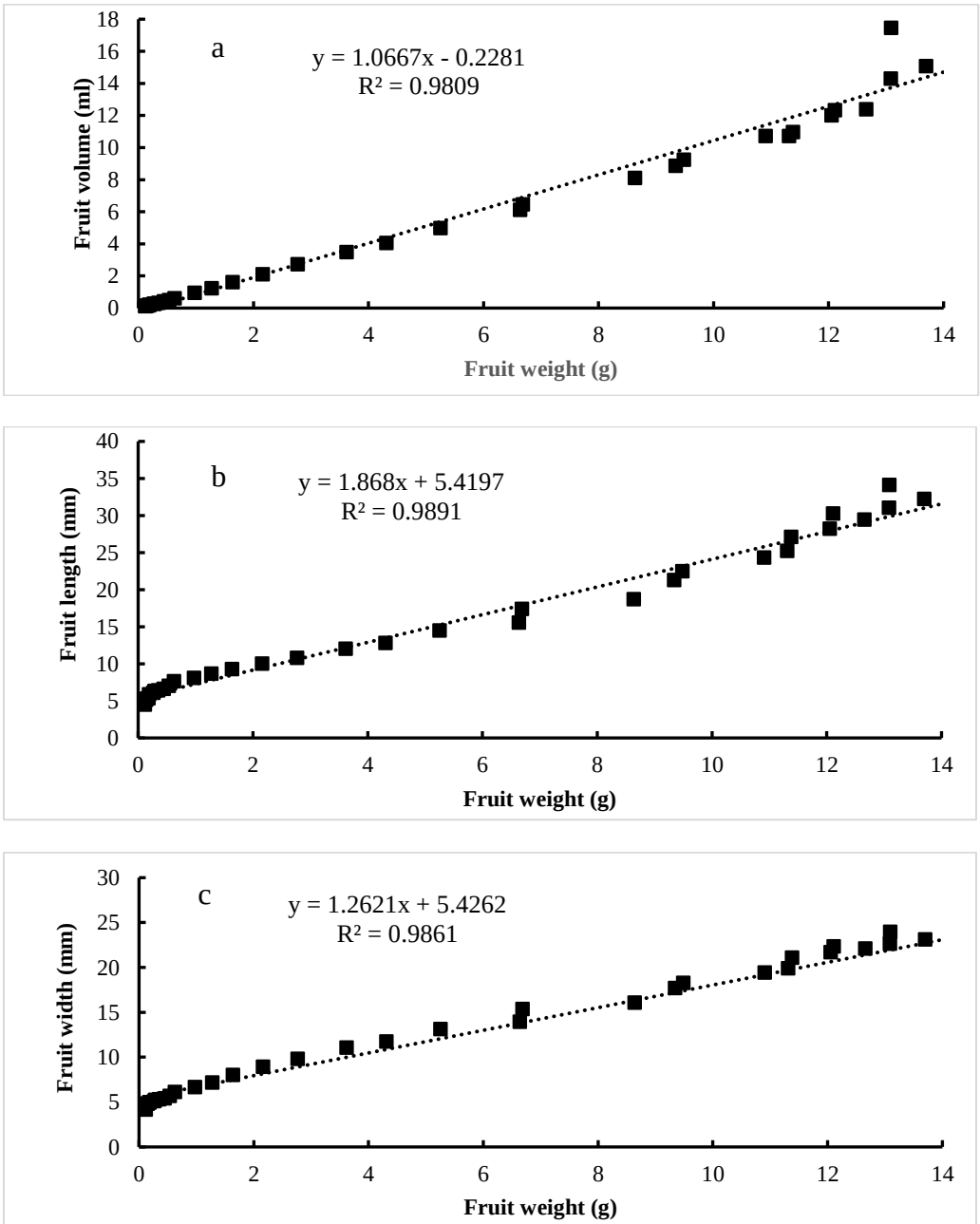

Fig. 4. Correlation of fruit weight between fruit volume (a) , width (b) and length (c) in 'Sukkary'

Cell division and expansion related to early thinning. An early thinning of date palm by cutting the strand (spikelet) while keeping 12 fruits per spikelet were done (cut bunch) and were compared to unthinned bunches (non- cut bunch) (Fig. 5). The growth curve of fruit volume in bunch cut and non-cut started to diverge in both varieties before the curve of fruit weight. In both varieties, the divergence of the two curves (cut and non-cut) occurred around 75 days after pollination, in fruit volume and at 85 days after pollination, in fruit weight.

(a) (b) (c)

Fig. 5. Fruits harvested from trees bunch cut at without thinning (control) (a); with hand thinned bunch (b); and 12 fruits per spikelet (c).

In general, date farmers agree on the fact that hand thinning is done when date fruit width reaches the size of chickpea grain (about 7 mm). Chickpea grain size is reached at 30 and 44 days after pollination, respectively for 'Sukkary' (Fig. 6.) and 'Khlass' (Fig. 7.). In both varieties, when the fruit size increased, the fruitlet was already at the end of phase I and beginning of phase II which means that the cell number was already determined. Early bunch cut (at pollination time) was considered to therefore important at this stage to further increase fruit size.

In rabbit eye blueberry, the number of cells was found to be the primary factor determining fruit size rather than the cell size (Johnson et al. 2011). Similar findings were observed in Japanese pear (*Pyrus pyrifolia* Nakai) (Zhang et al. 2006). There is a completion of cell division and beginning of cell wall thickening in the endosperm of Mejdool date fruit at 9 weeks after pollination (63 DAP) (Darleen et al. 1989). Few mitotic cells remain at 11 weeks (99 DAP). Depending on the layer, cell expands together with thickening of cell wall, which lasts from 9-17 weeks (63 to 119 DAP). At 17 weeks (119 DAP), all cells had completed their elongation phase resulting to maximum fresh weight of fruits. In apple, fruits thinned at earlier stage were able to increase in weight and cell number. But fruit from trees thinned beyond 10 DAP and fruit from unthinned trees were not able to develop beyond a weight of 190 g or 50 million cortex cells. This is presumably because early thinning allows the fruit to continue cell division in later stage of fruit development (Goffinet et al. 1995).

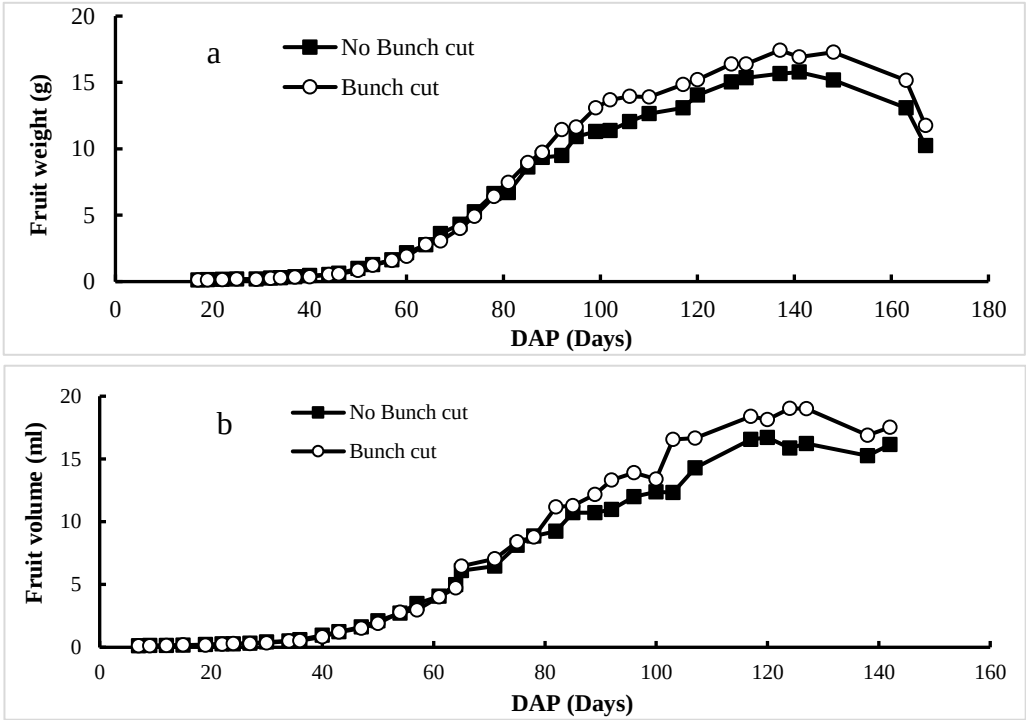

Fig. 6. Effect of thinning (bunch cut) on weight (a) and volume (b) on 'Sukkary' fruits.

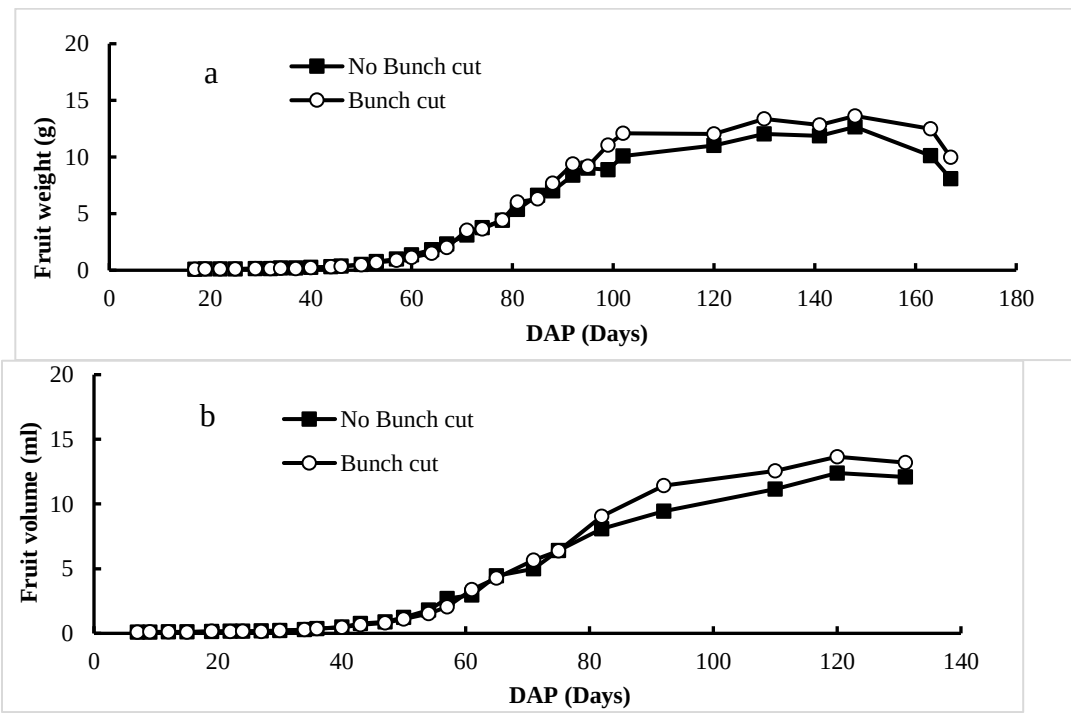

Fig. 7. Effect of thinning (bunch cut) on weight (a) and volume (b) on 'Khlass' fruits.

Fruit thinning by bunch cut. Cutting of the bunch at the time of pollination and keeping 12 fruits on each spikelet generated a significant increase in weight of 10-year-old Sukkary (17.4 g) (Table 1). The fruit weight with thinning was higher than that of with hand thinning (16.2 g) and in trees without thinning (13.7 g). Choosing 12 fruits per spikelet is based on the previous unpublished studies on different date varieties where it was suggested that 12 is the optimum number of fruits per spikelet to improve both fruit quality and yield.

Considering the positive effect of bunch cut on the fruit size compared to hand thinning, bunch cut was seems to more efficient to use in operation as it requires less manpower. On 10-year-old date tree bearing 12 bunches, hand thinning has daily productivity of 3 trees/worker while for bunch cut, the daily productivity is increased to 20 trees/worker. In apple, thinning affects mainly the fruitlet cell division, rather than cell expansion. Early thinned fruits (near bloom) have more cells in the fruitlet than those that were thinned at later stage or fruitlets that were left with no thinning. This resulted to bigger fruit size at harvest compared to those of thinned later and non-thinned (Goffinet et al. 1995). In addition, the differences in mature fruit size among olive cultivars may be mainly due to the differences in mesocarp size, which in turn were largely determined by cell number (Rapoport et al. (2004). Similar phenomena in apple and strawberry were suggested by Smith (1950), and Cheng and Bren (1992), respectively.

In this study, it was hypothesized that when cutting the bunch at the time of pollination, all the fruits should be removed from the beginning as there will be a competition for water and nutrients even before fruit formation. This method could allow the fruit to maximize its growth. In the case of hand thinning that was done on day 40 after pollination, the removed fruits already exerted a competition on water and nutrients during lag phase and part of linear phase.

In this study, there was a reduction in mean fruit mass when the time of hand thinning was delayed. Thinning done on apples at different times demonstrated significant effects on the final fruit size. These differences are closely associated with the differences in cell numbers in the cortex and that smaller fruit size produced by heavily cropping trees can be attributed to low cell number. Cell number is an important component in determining final fruit size. The time of thinning has a great influence on the mean fruit mass. Moreover, flower thinning at the pink bud stages and towards the end of flowering stage also has significant effects on greater fruit weight (Szot 2010).

CONCLUSION

The growth physiology of date palm *(Phoenix dactylifera*) 'Sukkary' and 'Khlass' was studied by comparison of growth pattern in weight, volume, length and width. Understanding the time of transition in growth phase of date fruits of different varieties is important to determine the approach on fruit maintenance to obtain sufficient water and nutrient supply in the crop, hence improving the quality of the palm date fruits. It was suggested that bunch cutting at the time of pollination and maintaining 12 fruits per spikelet were promising alternatives to hand thinning. The information might well contribute to further understand the physiology and improve the production of palm dates in Southeast Asia and other countries producing and exporting the fruits.

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Table 1. Effect of bunch cut on different growth parameters of Sukkary fruit.

	Number of fruits per spikelet	Yield per tree (kg)	Yield per bunch (kg)	Fruit weight at Tamar stage (g)	Flesh weight (g)	Seed weight (g)	Flesh weight/ Seed weight	Number of fruits per kg
Non-thinned trees	25	47.9±0.004 a	3.7±0.004 a	13.7±0.18 c	12.4±0.17 c	1.3±0.33 b	9.3±0.26 c	72.8±1.2 a
Hand thinning	16	48.4±0.30 a	3.7±0.30 a	16.2±0.15 b	14.9±0.14 b	1.4±0.33 a	11.0±0.28 b	61.7±0.58 b
Cut at 12 fruits	12	49.3±0.43 a	3.8±0.43 a	17.4±0.28 a	16.0±0.30 a	1.4±0.33 a	11.7±0.47 a	57.6±1.2 c

Values represent the means of 9 bunches per treatment ±SD. Different letters indicate significant differences between treatments ($p \leq 0.05$).

REFERENCES CITED

Akar, R. and C. Aydin. 2005. Some physical properties of gumbo fruit varieties. J. Food Eng. 66: 387–393.

Al-Yahyai R. and A. Manickavasagan. 2012. An overview of date palm production. Dates: production, processing, food, and medicinal values. New York: CRC Press. pp. 3-12.

Amanat, A., Waly, M., Essa, M. and S. Devarajan. Nutritional and medicinal value of date fruit. 2012 Dates: production, processing, food, and medicinal values. New York: CRC Press. pp. 361-37.

Beyer, M., Hahn, R., Peschel, S., Harz, M. and M. Knoche. 2002. Analyzing fruit shape in sweet cherry (*Prunus avium* L.). Sci. Hortic. 96, 139–150.

Cheng, G.W. and P.J. Breen. 1992. Cell count and size in relation to fruit size among strawberry cultivars. J. Amer. Soc. Hort. Sci. 117:946-950.

Darleen A. DeMason, K. N., C. Sekhar and M. Harris. Endosperm development in the date palm (*Phoenix dactylifera*) (Arecaceae).1989. American Journal of Botany. 76 (9): 1255-1265.

FAO. 2017. FAOSTAT. Food and Agriculture Organization of the United Nations.

Goffinet M.C., Robinson T.L. and A.N. Lakso. 1995. A comparison of 'Empire' apple fruit size and anatomy in unthinned and hand-thinned trees. J. Hort. Sci. 70: 375-387.

Gribaa A, Dardelle F, Lehner A, Rihouey C, Burel C, Ferchichi A, Driouich A. and J.C. Mollet. 2013. Effect of water deficit on the cell wall of the date palm (*Phoenix dactylifera* 'Deglet nour', Arecales) fruit during development. Plant, Cell and Environment. 36:1056-1070.

Jasim A, Fahad M. Al-Jasass and M. Siddiq. 2013. Date Fruit Composition and Nutrition. In: Muhammad Siddiq, Salah M. Aleid, Adel A. Kader, 2013. Dates: Postharvest Science, Processing Technology and Health Benefits. pp. 261-283.

Johnson, L. K., A. Malladi and D. S. NeSmith. 2011. Differences in cell number facilitate fruit size variation in Rabbiteye blueberry genotypes. J. Amer. Mar. Soc. Hort. Sci. 136: 10– 15.

Khoshnam, F., Tabatabaeefar, A., Varnamkhasti, M.G. and A. Borghei. 2007. Mass modeling of pomegranate (*Punica granatum* L.) fruit with some physical characteristics. Sci. Hortic. 114: 21–26.

Mechlia, N.B. and J.J. Carroll. 1999. Agroclimatic modeling for the simulation of phenology, yield and quality of crop production. I. Citrus response formulation. International Journal of Biometeorology 33: 36- 51.

Musselman, L. J. 2007. Figs, Dates, Laurel and Myrrh: Plants of the Bible and the Quran. Timber Press, Inc, Portland, OR, pp. 114 - 119.

Rahmani, A. H. Aly, S.M. Ali, H. Babiker, A.Y. and S. Srikar. 2014. Therapeutic effects of date fruits (*Phoenix dactylifera*) in the prevention of diseases via modulation of anti-inflammatory, antioxidant and anti-tumour activity. International journal of clinical and experimental medicine. 7 (3): 483.

Rapoport, H. F., Manrique, T. and R. Gucci. 2004. Cell division and expansion in the olive fruit. Acta Horticulturae, (636): 461–465.

Smith, W. H. 1950. Cell-multiplication and cell-enlargement in the development of the flesh of the apple fruit. Annals of Botany. Land. 14: 23-38.

Szot, I. 2010. Flower and fruit thinning effects on the development and quality of 'Sampion' apple fruits. Journal of Fruit and Ornamental Plant Research, 18:129-138.

Tabatabaeefar, A. and A. Rajabipour. 2005. Modeling the mass of apples by geometrical attributes. Sci. Hortic. 105:373–382.

Tabatabaeefar, A., Vefagh-Nematolahee, A. and A. Rajabipour. 2000. Modeling of orange mass based on dimensions. J. Agric. Sci. Technol. 2 (4):299–305.

Tejero, I.G., Vicentea, R.R., Bocanegraa, J.A., Garcíaa, G.M., Zuazoa, V.H.D. and J.L.M. Fernándeza. 2010. Response of citrus trees to deficit irrigation during different phenological periods in relation to yield, fruit quality, and water productivity. Agricultural Water Management 97: 689-699.

Tengberg, M. 2012. Beginnings and early history of date palm garden cultivation in the Middle East Journal of arid environments. 86:139-147.

Yin Y., Zhang X., Fang Y., Pan L., Sun G., Xin C., Ba Abdullah MM., Yu X., Hu S., Al-Mssallem I.S. and J. Yu. 2012. High-throughput sequencing-based gene profiling on multi-staged fruit development of date palm (*Phoenix dactylifera*, L.). Plant Mol Biol. 78 (6):617–626.