Available online at www.asric.org

ASRIC Journal on Water, Energy & Environment 1 (2020) 1-8

Yield and Quality of Date Palm (*Phoenix dactylifera L.*) Product under Deficit Irrigation Regimes in Dry Conditions

Ali Widaa Mohammed Elamin [a,1], Hussam Eldeen Ismail Ali Omer [b]

[a] *Dept. of Agric. Eng., Faculty of Agriculture, University of Khartoum-Sudan*
[b] *Alkharj Center for Date Palm Research, Kingdom of Saudi Arabia*

Received 9 December 2019; revised 30 August 2020; accepted 30 October 2020

Abstract

This study was conducted to determine appropriate irrigation amount, fruit quality and water-yield relationship for date palm under dry conditions. The research work was carried out in Alkharj, Kingdom of Saudi Arabia, for two consecutive seasons (2016-2017) and (2017-2018). The treatment contained four irrigation water amounts, (ETC 100%, ETC 75% and ETC 50%) of date palm tree water requirement and the amount of water actually used (control). A mature date palm trees (Segae variety) of the same age (10 years) were selected randomly to perform the experiment in both seasons. The experiment was organized in Complete Block Design (CBD) and the analysis was done using SPSS. The measured parameters were water productivity (kg/m^3), yield parameter's (weight of date fruit /g and productivity kg/tree), and quality parameter's (moisture content (%), total soluble solid (TSS %), Brominated (%) of date fruit and Veneer (%)). Moreover, the quality of irrigation water used, was assessed and compared with FAO standard for irrigation water. The result showed that the water quality was found within the permissible level of FAO standard for irrigation water. The result also indicated that the amount of water using in the study area, is more than the actual amount of water needed by date palm tree (ETc100%) according to the local weather. Moreover, the water treatment (75% ETc) showed the highest significant differences ($P \leq 0.05$) of water productivity, moisture content, and (TSS%). While water treatment (100% ETc) revealed the highest values of productivity in both seasons followed by (75% ETc). Moreover, the Brominated and Veneer values were found within the recommended level according to the local standard. However, the water treatment (50% ETc) showed a high significant difference ($P \leq 0.05$) in compared with others treatments. This study concluded that date palm can growth perfectly with high yield and product quality with water regime ETc 75%. Therefore, huge amount of water can be saved when adopting this regime for date palm production.

Keywords: Deficit irrigation; Date palm; Water productivity; Date palm fruit quality

1. Introduction

The Kingdom of Saudi Arabia, covered an area of 2.15 million km², is by far the largest country on the Arabian Peninsula. Saudi Arabia lies in the tropical and subtropical desert region. Therefore, it is facing great challenges due to its limited water resources for agricultural development and sustainability. Searching for new water resource in Saudi Arabia is too difficult and very expensive process, so the shortest way to maximize the water use efficiency through optimizing water use and determination the actual crop water requirements. The overestimation of water requirements result in wastage of precious

[1]Corresponding author. *Email addresses:* aliwidaa59@yahoo.com, amelamin@uofk.edu (A.W.M. Elamin)

water resources and impacts adversely on the economic, social and environmental levels. A correct estimation of ETc improving water management by changing the volume and frequency of irrigation based on actual crop water requirements and soil characteristics. Moreover, enhancement of irrigation systems and water saving regimes identified as a main factors of reducing agricultural water demand (Horst et. al., 2005).

The date Palm tree is (the tree of life in the desert areas) is the one of the oldest trees known to man which is cultivated since ancient times. Nowadays, studies and trials are continued to develop agricultural operations that needed to produce date Palm such as water requirement, fertilization …..etc.

The estimation the numbers of date palm trees in the world is approximately 100 million Palm, there are 80 million palm trees in the Arab world alone, which is equivalent to 80% of number of palms in the world, and average annual production of about 3 million tons /year, which is equivalent to 80% of the world production of dates.

The date palm tree is considered as one of the most important fruit for its high nutritional value, as well as it is well adapted to harsh arid climate, (Bhat *et.al.,* 2012). The previous studies showed that date palm tree produces one kg of fruits using about 2 m^3 of water. While, Barreveld, (1993), stated that the water requirements of date palm tree varied according to the climate, crop age and location. The seasonal gross irrigation requirements for date palm offshoots were 2191 m^3/ha/year, while the farmers added water nine times as much as the actual gross irrigation requirements. (Abdurrahman, *et al.*, 1996). Therefore, Bhat *et.al.,* (2012), reported that in the perennial crops it is essential to know both total and seasonal water requirements as to tie between plant water requirements with the available water supply. In KSA, the date palm annual evapotranspiration is approximately 1644 mm, while the crop coefficients values ranged from 0.56 to 0.70. (Kassem, 2007). The date palm tree is considered one of the most tolerant plant for water deficit and high temperature but at the end these conditions will affect the quantity and quality of crop yield. Some differences in dates water requirement according to the climate and locations has been recorded, which was ranged between 1500 to 3500 mm in Algeria, 2700 to 3600 mm in the United State, 2230 mm in Egypt, 2500 to 3200 mm in Iraq, and 1300 to 2500 mm in South Africa. In Tunisia the monthly water consumption ranged between 134mm to 165mm. (Liebenbag, and Zaid, 2002). Alazaba, (2001), estimated date palm crop evapotranspiration theoretically using Penman-Monteith equation in six different locations to be from 1500 to 5000 mm according to location and irrigation water quality.

The determination of water quantities are the most important factors that affecting the cultivation of various crops. Moreover, it helps in improving yield and quality of the products. However, the studies that held to investigate the effect of water amount on the date palm production under dry condition are limited. Therefore, for the economic and nutrition value of the date palm this study is designed. The aim of this study was to determine appropriate irrigation amount and water-yield relationship for date palm production and its effect on the quality and quantity of the product under dry condition.

2. Material and Methods

The experimental work was carried out at the AL Rajhi farm, at 80 kilometers south of Riyadh town, Kingdom of Saudi Arabia (47.5° E, 24.17 ° N). The region is classified as a semi-arid with great variation in temperature and rainfall. The soil is sandy clay loam. The experiment was conducted during two consecutive seasons (2016 and 2017) in an area of 1.5 acre occupied by 200 date palm trees at spacing of 8×8m.

Numbers of mature date palm trees (Segae variety) of the same age (10 years) were selected randomly, then were divided into four groups each group irrigated by specific amount of water, 100 %, 75 %, 50 % of date palm tree water requirement and the amount of water that traditionally used in the site. The experiment was organized in Complete Block Design (CBD) with five replications, while the analysis was done using SPSS.

Estimation of the date palm water requirement (ETc.) is derived from crop evapotranspiration (crop water use) which is the product of the reference evapotranspiration (ETo) and the crop coefficient (Kc).

The reference evapotranspiration (ETo) was estimated based on the FAO penman – Monteith equation, using climatic data (Hanson and May, 2004) as following:

$$\mathrm{ETc} = \mathrm{ETo} * \mathrm{Kc} * \mathrm{Ks} * \mathrm{Kr} \quad (1)$$

ETc = crop evapotranspiration (mm/day).
Kc = crop Coefficient (dimensionless).
ETo = Reference evapotranspiration (mm/day).
Ks = soil water availability factor.
Kr = A reduction factor.

The amounts of water (100%, 75%, and 50% of ETc,) were determined using the following equation as described by Makki and Mohamed, (2005)

$$V = \frac{ETc * I * A}{Ea} \quad (2)$$

Where:
V= Volume of water to be applied for each tree per irrigation (liters).
ETc = crop water requirement (mm/day).
I=Irrigation frequency (days).
A=the area specified for each tree m^2.
Ea= application efficiency (80%)

Date palm fruits were harvested and placed in plastic boxes. Then after, Italian digital balance was used for recording date fruit weight in g per fruit and kg per tree. Therefore, random samples were taken to represent the treatment and the number of fruits in each sample were determined. Moreover, the fruit quality test was done, where moisture content (%), Total soluble solid (TSS%), Brominated (%) and Veneer (%) were measured. The moisture analyses were done for each sample to determine Moisture content (%) of date fruit, firstly the fruit Seed was removed then the fruit weighted and dried using oven under 105 °C for 24 hours. Secondly the following equation was used as stated by Taha and Al Ghtani, (2015):

$$Moisture\ content\% = \frac{m_1 - m_2}{m_1} \times 100 \quad (3)$$

Where: m_1 weight of fruit before drying, and m_2 weight of fruit after drying.

The Total Soluble Solid (TSS%) of samples was determined using Digital handheld refractometer. TSS contained mainly sugars and other substances which vary according to the date palm verities. While the Brominate and veneer were estimated by collecting random samples of palm date fruits at dry stage and one kg weight for each sample. Then after the samples were sent to the laboratory for sorting and grading. Moreover each sample was divided into two groups, the first was brominated date (it is difficult to separate peel from flesh of the date fruits) and the second was veneer date (the flesh clearly separated from peel). Then the brominated date percentage and veneer percentage were calculated using the following equations:

$$Brominated\ Percentage(\%) = \frac{Weight\ of\ brominated\ fruits\ (kg)}{Total\ weight\ (kg)} \times 100 \quad (4)$$

$$Veneer\ Percentage(\%) = \frac{Weight\ of\ veneer\ fruits\ (kg)}{Total\ weight\ (kg)} \times 100 \quad (5)$$

The water productivity for each tree was determined as follows:

$$Water\ Productivity\ \ Kg/m^3 = \frac{Yield\ kg/tree}{Consumptive\ use\ weight\ m^3/tree} \times 100 \qquad (6)$$

3. Results

The source of water used to irrigate date palm tree is well water, which its quality is shown in Table 1. The obtained results were compared with the irrigation water quality standard of Food and Agricultural organization of United Notions (FAO). The result revealed that all the measured parameters of water quality were found within the slight to moderate problems, except the potassium which was found exceeding the severe level.

Table (1), the quality of water used in irrigating date palm compared with FAO standard.

	Units	The used water	FAO standard		
			none	Slight to Moderate	severe
EC	dS/m	1.52	<0. 7	0.7-3	>3
SAR		4.54	>0. 7	0.7-0.2	<0.2
Na	meq/l	8.17	< 3	3-9	>9
Mg	meq/l	3.00	20		
Ca	meq/l	3.35	42		
Cl	meq/l	8.48	<4	4-10	>10
B	mg/l	-	< 0.7	0.7 – 3.0	> 3.0
K	mg/l	6.3	2		
NO_3-N	mg/l	6.4	<5	5-30	>30
P	meq/l	-			
CO_3	meq/l	-			
HCO_3	meq/l	2.24	<1. 5	1. 5-8. 5	>8. 5
Fe	meq/l	0.012	5. 0		
Mn	meq/l	0.006	0.2		
Zn	meq/l	0.003	2		
Cu	meq/l	0.001	0.2		
pH		7.4	6. 5 – 8. 4		

The date palm water requirement is varied according to the different regions even in the same country, cultivar variety and from month to another. Fig. 1 showed that the application amount of water is commonly used in the experimental location (control) is more than the actual amount of water needed by date palm (ETc100%) according to the climate of the study area.

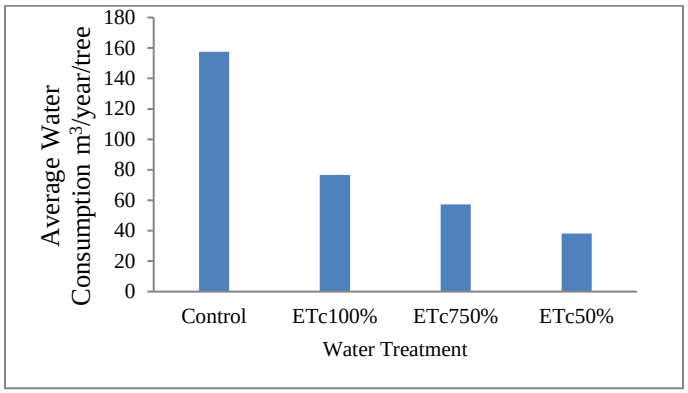

Figure 1. The annual average water consumption m^3/tree of date palm tree

Understanding of water use for crop production is an important and essential. Consequently, the water productivity of date palm is investigated and the result indicated in Fig. 2. The result showed that the water treatment ETc75% revealed the highest value of water productivity, while the control shown the lowest one.

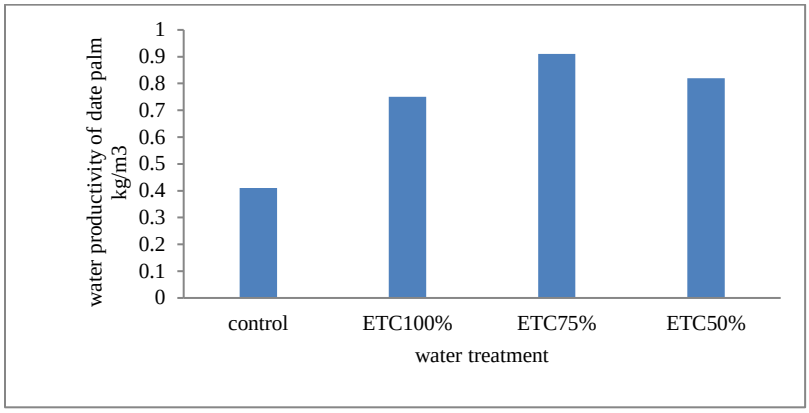

Figure 2. Effect of water treatment on water productivity kg/m^3 of date palm tree

As shown in Tables 2 and 3, the weight of date palm fruit in gram and the total yield kg/tree tend to increase with increasing amount of water. Therefore, the water treatments (ETc100%) reviled significant difference ($P<0.05$) compared with the other water treatments.

Table 2. Effect of water treatment on the Average weight of date palm fruit (g)

water treatments	Average weight of date fruit (g)	
	Season 2016	Season 2017
ETC100%	12.275 ^{b}	12.275 ^{b}
ETC75%	11.020 ^{c}	12.025 ^{b}
ETC50%	11.005 ^{c}	10.615 ^{c}
control	12.390 ^{b}	12.390 ^{b}
Local standard	14.000 ^{a}	14.000 ^{a}
LSD	0.501	0.514

Means followed by the same letters in the same column are not significant difference at $P\leq 0.05$

Table 3. Effect of water treatment on the total date palm fruit's weight kg / tree

water treatments	Total fruit weight / tree	
	Season2016	Season2017
ETC100%	60.20 ^{b}	59.30 ^{b}
ETC75%	54.70 ^{d}	54.70 ^{c}
ETC50%	29.05 ^{e}	36.30 ^{e}
control	57.00 ^{c}	51.85 ^{d}
Local standard	65.00 ^{a}	65.00 ^{a}
LSD	2.551	2.432

Means followed by the same letters in the same column are not significant difference at $P\leq 0.05$

According to the local standard the required moisture content (%) in date palm fruit is about 18%. However the near value to the local standard is recorded with water treatment ETc75%, (Fig. 3). On the other hand the water treatment ETc75% recorded a high significant difference ($P \leq 0.05$) over the other water treatments, in increasing fruit content of the Total Soluble Solid (TSS %), (Table 4).

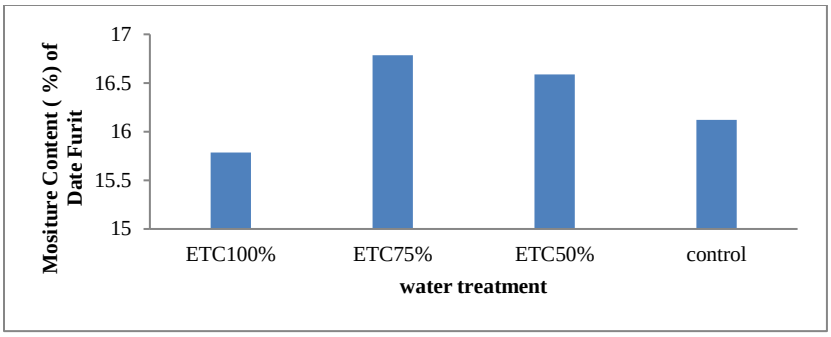

Figure 3. The effect of water treatment on date palm fruit's moisture content (%)

Table 4. Effect of water treatment on the TSS content (%) of date fruit

water treatments	TSS (%)	
	Season2016	Season2017
ETC100%	58.50 [b]	61.50 [a]
ETC75%	61.10 [a]	60.05 [a]
ETC50%	53.80 [c]	53.80 [b]
control	53.80 [c]	61.50 [a]
Local standard	60.00 [ab]	60.00 [a]
LSD	1.793	2.186

Means followed by the same letters in the same column are not significant difference at P≤ 0.05

The water treatments ETc50 % revealed the highest values of brominated and veneer percentages of the date palm fruit Figs. 4 and 5.

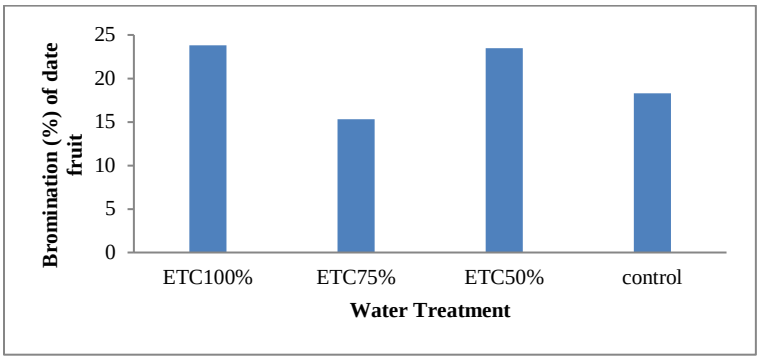

Figure 4. The effect of water treatment on brominated (%) of date palm fruit

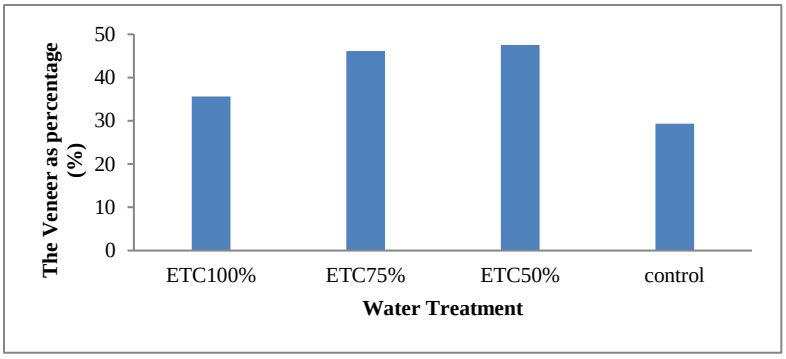

Figure 5. The effect of water treatment on veneer (%) of date palm fruit

4. Discussion

Irrigation water irrespective of its sources contain considerable amounts of chemical substances that may adversely affect crop yield and soil fertility (Maas, 1990). Crops vary in its tolerance to salinity problem, which depend on cultural condition and management practices. Therefore the obtained result, as shown in Table 1, is considered within tolerant level of date palm according to Maas, (1990). Moreover, date palm may be grown without stress with moderate saline and bear full crop load under 2000 ppm saline water and decrease significantly with 5000 to 8000 ppm level of water salinity. But attention should be given for the future use because the continues usage may lead to accumulation of salt in soil, which affect adversely growth and yield of the crop, (Al-Rasbi, 2010).

The results that presented Fig. 1, may be attributed to mismanagement, because the date palm cultivars response differently to irrigation regimes according to Al-Rawi and Al-Mohemady, (2001) and Dawoud, (2001). Thus, each cultivar's irrigation practices need to be clearly defined. on the other hand, judicious use of water is a most important agenda should be considered in current and future planning of using water resources precisely in areas suffering from water scarcity. Therefore the accurate calculation of date palm water requirement based on cultivar type is highly needed.

As indicated in Fig. 2, the current result is considered promising results which minimizing the water usage and improving crop yield. Hence, this result represents a good finding for the water usage and planners to base their future usage of water resources, which will face a significant decrease in the whole world and in particular the Middle East and North Africa, according to Al-Rimmawi, (2012). Moreover, the implementation of best water management in term of each drop for more food crop is needed for sustainable crop growth and enhanced productivity and fruit quality. Saeed *et al.,* (1990), stated that irrigation water stress significantly depress root elongation, reduce fruit number, size and weight. Moreover, Amiri *et al.,* (2007) and Al Amoud *et al.,* (2000), concluded that a general trend of increasing in yield always comes with proper watering and water availability.

The obtained results as shown in Tables 2 and 3, were found within the accepted range of date palm fruit size (2-60 g) according to the type of the cultivar, as stated by Zaid, and Wet, (2002) and also agreed with finding of Sueleman, (2014). Also The current results agreed with finding of (AI-Amoud *et al.,* 2012), who stated that the yield of date palm tends to increase with increasing in irrigation quantity. Moreover, Ibrahim *et al.,* (2012), reported that the growth parameters of date palm significantly affected by the amount of water.

Figure 3 and Table 4 explained the results of fruit moisture content and TSS%. The current results supported by the finding of Assirey, (2015), who reported that moisture content of date fruit found within the range of 10.5 - 29.5 %. The total soluble solid (TSS %) is considered as one of the most important quality factors that affect the commercial value of date fruit. the major constituents of the TSS % are sugar forms and it is a good estimate of total sugar content (Farag and Al-Masri, 1999). Also the current results are supported by the finding of Al-Yahyai and Al-Kharusi, (2012) who reported that chemical quality attributes of date palm varied in response to decreased frequency of irrigation water applied during fruit development. Also stated that the total soluble solid (TSS%) content such as pectin, and dry matter were high under deficit irrigation.

As in Figs. 4 and 5 the percentages of brominated and veneer tend to increase with decrease in irrigation water amount, and this approved by Al-Yahyai and Al-Kharusi, (2012).

5. Conclusion

The conclusion of this study is that water deficit regime ETc 75% of date palm showed high water productivity and good product quality (TSS % Moisture content % and fruit weight). Therefore, adopting of this regime for producing date palm under dry condition can save huge amount of water.

References

Abdurrahman, W.A. and Al-Nabulsi, Y.A. 1996. Irrigation Water Use of Date Palm," Proc. 3rd Symposium on the Date Palm, King Faisal University, Date Palm Research Center, Al-Hassa, S. Arabia, 1: 273-280.

Al-amoud, A. I.; Mohammad, F. S.; Al-Hamed, S. A. and Al-abdulkader, A. M. 2012. Reference Evapotranspiration and Date Palm Water Use in the Kingdom of Saudi Arabia. Agricultural Engineering Dept., College of Food and Agriculture Sciences, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia.

Alazaba, A.A. 2001. Theoretical Estimate of Date Palm Water Requirements Using Penman-Monteith Model. A paper number 012100, 2001 ASAE annual meeting.

Al-Rasbi, S.A.R. 2010. Evaluation of the Growth of Date palm Seedlings Irrigated with Saline Water in Sultanate of Oman. Ph. D. Thesis, Department of Landscape Ecology and Nature Conservation, University of Kassel, Germany.

Al-Rawi, A.A.H. and Al-Mohemdy, A.F. 2001. Effect of Water Quality on Growth and Yield of Date Palm (*Phoenix dactylifera L.*) Proceedings of the 2nd International Conference on Date Palm, Al-Ain, UAE, pp. 128–136.

Al-Rimmawi, H. 2012. Middle East Chronic Water Problems: Solution Prospects. *Energy and Environmental Research*, 3(1): 28-34.

Al-Yahyai, R. and Al-Kharusi, L. 2012. Physical and Chemical Quality Attributes of Freeze Stored Dates. *Int. J. Agric. Biol*. 14:97–100.

Amiri, M.E.; Panahi M. and Aghazadeh A. 2007. Comparison of Bubblers, Sprinkler and Basin Irrigation for Date Palm (*Phoenix dactylifera L.*, cv. *Zahdi*) Growth in Kish Island, Iran. *Journal of Food, Agriculture and Environment* 5(3),185-187.

Assirey E. A. R. 2015. Nutritional Composition of Fruit of 10 Date Palm (*Phoenix dactylifera L.*) Cultivars Grown in Saudi Arabia. J. of Taibah University for Science, 9 (1); 75-79.

Barreveld, W.H. 1993. Date Palm Products, FAO Agricultural Services, Bull. No. 101, Rome, http://www.fao.org/docrep/ t0681E/ t0681e00.ht

Bhat, N.R. V.S.; Suleiman, M.K.; Thomas, B.; Ali, S.I.; George P. and Al-Mulla L. 2012. Estimation of Water Requirements for Young Date Palms Under Arid Climatic Conditions of Kuwait. ISSN 1817-3047. World Journal of Agricultural Sciences 8 (5): pp 448-452.

Dawoud, D.H. (2001). Effect of Different Irrigation Intervals on the Growth Rate, Yield and Fruit Quality of MWL and MWK Date Palm Cultivars. Proceedings of the 2nd International Conference on Date Palm, Al-Ain, UAE, p. 138. http://www.pubhort.org/datepalm/datepalm2/datepalm2-14.pdf

Farag, K. and Al-Masri, H. 1999. Extending the Khalal Stage of "Khesab" Dates Using New Method of Packaging and Modified Calcium Formation. Emir. J. Food Agric. 11(1):21- 30.

Hanson, B and May, D. 2007. The Effect of Drip Line Placement on Yield and Quality of Drip-Irrigated Processing Tomatoes. Irrigation and Drainage System. (21): 109-118.

Horst, M.G.; Shamutalov, S.S.; Pereira, L.S. and Gonc¸alves, J.M. 2005. Field Assessment of the Water Saving Potential with Furrow Irrigation in Fergana, Aral Sea basin. Agric. Water Manage. 77: 210–231.

Ibrahim, Y. M.; Saeed, A.B. and Mohammed Elamin, A. W. 2012. Effect of Irrigation Water Management on Growth of Date Palm offshoots (Phoenix dactylifera L) under the River Nile State Conditions. University of Khartoum J. Agric. Sci. 20(3): 275-285.

Kassem, M.A. 2007. Water Requirement and Crop Coefficient of Date Palm Trees" Sukariah CV". Misr J. Ag. Eng., 24(2): 339-359.

Liebenbag, P.J. and Zaid, A. 2002. Date Palm Irrigation. FAO Plant Production and Protection Papers- 156 Rev. 1.

Maas E.V. 1990. Crop Salt Tolerance. In: Agriculture Salinity Assessment and Management Manual. K.K. Tanji (ed), ASCE, New York: 262-304.

Makki, E.K. and Mohamed, A.E. (2005). Wheat Response to Irrigation Scheduling. University of Khartoum Journal of Agricultural Sciences 13 (1), 53- 67.

Saeed, A.B.; Etewy, H.A. and Hassan, O.S.A. 1990. Watering Requirement and Scheduling of Date Palm. Journal of Agricultural Mechanization in Asia, Africa and Latin America, 2(4: 49-52.

Sueleman N. M. 2014. Spectroscopic Determination of Some Trace Elements as Pollutants in Fruit Dates Palm and Agricultural soil at Zilfi Province. J. of Anal. Chem., 2(3): 11-16.

Taha, K. K. and Al Ghtani, F. M. 2015. Determination of the Elemental Contents of Date Palm (Phoenix dactylifera L.) from Kharj Saudi Arabia. World Scientific News 6: 125-135.

Zaid, A. and de Wet, P.F. 2002. Botanical and Systematic Description of the Date Palm, in: A. Zaid (Ed.), Date Palm Cultivation, Food and agricultural organization of the United Nations pp. 1–28.