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Determination Of The Appropriate Irrigation Interval Based On Soil Moisture Depletion Of Date Palm (Phoenix Dactylifera L.)

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Abstract

A field experiment was conducted in a date palm farm, southern Iraq, during the 2019 and 2020 seasons, and the purpose of the study was to determine the appropriate irrigation interval for date palms based on soil moisture depletion (SMD) and water consumption, and the effect of SMD on growth, yield and water productivity, three levels were used 30%, 40%, 50% as a percentage of total available water (TAW), from which three intervals were determined, the treatments were placed in a randomized complete block design with three replications. The depth of irrigation water that is applied on the basis of evapotranspiration for each treatment was 50, 66, 83 mm respectively, for SMD treatments. Analysis of variance showed that soil moisture depletion had a significant ($P < 0.05$) effect on the yield, annual growth of fronds, and water productivity. the highest average yield of dates is 34.2 and 37.2 kg.palm-1 for 30% SMD for the 2019 and 2020 seasons, with water productivity of 0.49, 0.53 kg.m-3, and the highest annual growth rate of fronds 20.22 and 26.40 cm.year-1 for the two seasons. In conclusion, although the date palm tolerates drought, it leads to a shortage of yield, due to the conditions of the study area. An irrigation interval is recommended when 30% of TAW is consumed with an irrigation depth of 50 mm to achieve the highest water yield with the highest yield and annual growth rate. Further research is also recommended in the field of SMD for palms for different conditions.

Key words: soil moisture depletion, irrigation interval, water productivity, date palm

1-Introduction

The agricultural sector is the main sector in water consumption in Iraq, and it is estimated that 85% of the water resources are used in agriculture and about 8% are used for other purposes (Ewaid et al. 2019). The higher temperatures in southern Iraq cause more evaporation (Al-Jawad et al. 2020). In hot, dry conditions where ETc is high, a short irrigation interval reduces the differences in moisture content of the wet area, providing favorable conditions for plant growth, and a long interval leads to a significant decrease in moisture content (Allen et al. 1998). El-Kosary et al. (2009) concluded that the soil moisture depletion by 25% gave the highest production of date palm. And Al-Yahyai and Al-Kharusi (2012) showed that the change in the irrigation interval can be used to improve some chemical properties and quality indicators of dates. Alhamd (2021) mentioned that there was a significant improvement in the productivity characteristics as a result of using the short interval. The date palm (Phoenix dactylifera L.) is one of the oldest cultivated fruit trees and was known in Iraq since 4000 BC (Khierallah et al. 2015). Palm cultivation is a cornerstone of Iraq's agricultural environment, and Basra Governorate is one of the most important date palm cultivation areas in Iraq. Iraq produces about 639,315 tons and an area of 213,032 hectares, according to the FAO statistics for the year 2019 (FAOSTAT, 2021). Doorenbos and Pruitt (1977) mentioned that the date palm is one of the drought-resistant plants, but when exposed to a long drought period, growth declines and stops, and the palm needs regular irrigation during the year to maintain growth and production in quantity and quality. In the conditions of the Kingdom of Saudi Arabia, the actual use of date palm water ranged from 59.4 to 80 $m^3.year^{-1}$ (Alamoud et al., 2012). Water productivity (WP) ranges in many date-producing countries as a general average of 0.18-0.37 $kg.m^{-3}$ (FAO, 2008). As such, the objectives of this research include (a) studying the effect of SMD on WP, yield and annual growth of fronds when using bubbler irrigation (b) determining the best monthly irrigation interval based on Soil moisture depletion and water consumption of Al-Sayer date palm cultivar in the arid environment of Shatt Al-Arab region, southeastern Iraq.

2- Materials and methods

1-2 study site

The experiment was conducted in the Shatt al-Arab district, Basra governorate, southern Iraq, located at latitude 30° 42' 50.0 north and longitude 47° 46' 59.0" east at an altitude of 5 m above sea level during two successive seasons 2019 and 2020, in soil. Clay texture classified as Fine Clayey, Mixed, Calcareous, Hypothermic, and typical Torrifluvents and within the soil series (DE45) according to the modern classification system (Kazim, 2017). Table 1 shows some of the primary physical and chemical properties of soil.

Table (1) shows some of the primary physical and chemical properties of soil.

Features		soil depth (cm)			
		0-30	30-60	60-90	90-120
Sand	gm kg-1	445	477	380	368.9
Silt	gm kg-1	260	189	205	254.1
Clay	gm kg-1	136	134	95.5	107
soil texture class		L	L	Si L	Si L
Weighted average diameter (mm)		0.35	0.13	0.13	0.119
Bulk Density (Mg.m-3)		1.27	1.32	1.38	1.42
Particle Density (Mg.m-3)		2.51	2.53	2.54	2.52
Field capacity 0.33 bar(%)		32.2	33.1	33.6	33.8
Permanent Wilting point 15bar (%)		20.6	20.2	20.4	20.4
Total Porosity (%)		49	48	46	44
Total Carbonate (gm.kg-1)		372	391	422	454.7
Organic matter (g.kg-1)		5.62	3.25	2.84	0.161
Moisture at field capacity (%)		31.4	32.7	32.8	33.45
Water saturated conductivity (m day-1)		3.14	2.14	0.49	0.21
Soil EC (ds.m-1)		4.5	4.8	6.7	7.18
pH		7.58	7.72	7.9	7.95
CEC (We will finance M-1)		9.21	12.5	16.2	18.24

1-3 Meteorological data

The climatic data for the Ktaiban region were collected for a period of 20 years, and the daily average of the data was calculated for a year, the modified Penman-Monteith equation was adopted in the measurement of reference evapotranspiration (Allen et al., 1998) using Cropwat program as shown in Table (2).

Table (2) the monthly average of climatic data and reference evapotranspiration for the experiment site as an average of 20 years

Mon.	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	Eto	Eff Rain
	℃	℃	%	km/day	hours	MJ/m /day	mm/day	mm
Jan	7	17.9	58.7	260	6.7	12	2.7	11.0
Feb	9	21.4	47.0	296	7.5	15	3.9	0.2
Mar	13	27.4	36.5	305	7.7	19	5.8	0.0
Apr	18	33.6	29.3	297	8.7	21	7.6	0.0
May	25	40.2	20.5	325	9.7	25	10.2	0.0
Jun	28	44.4	14.9	412	11.2	29	13.5	0.0
Jul	30	46.4	14.9	399	11.1	28	13.7	0.0
Aug	30	46.8	16.3	329	11.1	26	12.1	0.0
Sep	26	43.1	19.2	301	10.4	22	10.1	0.0
Oct	22	37.2	26.4	252	8.9	17	7.2	0.0
Nov	15	27.6	41.8	244	7.7	12	4.6	6.8
Dec	9	20.3	52.1	252	6.6	10	3.1	37.8

1-4 Designing the experiment and preparing the palm:

The experiment was conducted in the field on 45 palm trees as experimental units elected at the age of 7 years, producing dates that are highly homogeneous in terms of vegetative growth, size and age for the Al-Sayer variety, and the distance between the palms was 6*6 m. The experimental units were randomly distributed as a factorial experiment using the randomized complete block design (R.C.B.D). The irrigation network was done with a bubbler irrigation system. Then, horticultural service operations were conducted on palm trees. The number of cluster was standardized in all treatments, as four and five clusters were left for each palm for the 2019 and 2020 seasons, respectively.

1-5 Soil Moisture Depletion (SMD)

Three percentages of soil moisture depletion (SMD) were determined from total available water (TAW), where three SMD were adopted to express irrigation intervals, (30%, 40%, and 50%) and the calculated interval was applied as an average for each month.

The total available water content (TAW) represents the difference between the volumetric moisture content at a tension of 33 kPa, which represents the field capacity (FC), and the volumetric moisture content at a tension of 1500 kPa, which represents the permanent wilting point (PWP) in the effective root zone according to the following equation (Allen et al. 1998)

$$TAW = 1000\ (\theta_{FC} - \theta_{WP})\ Z_r \quad \text{-------- (1)}$$

TAW =Total available water content in soil (mm), θ_{FC} = volumetric moisture content at field capacity ($m^3.m^{-3}$), θ_{WP} = volumetric moisture content at permanent wilting point ($m^3.m^{-3}$), Zr = effective root depth (m) and 1.2 m was adopted for the palm, The tree can absorb 65% to 80% of the water within the root zone depth of no more than 1.2 m (yaacoob, 1996).

Readily available water (RAW) It represents water that the plant can absorb without being exposed to moisture stress and is calculated from the following equation (Allen et al. 1998):

$$RAW = SMD \times TAW \quad \text{------- (2)}$$

RAW = readily available water in the root area mm, SMD = moisture depletion ratio. The irrigation intervals were calculated per day for each month of the year based on the SMD from the total available water from the following equation: $Ii = \frac{RAW}{WR}$ ------- (3)

Ii = irrigation interval (day), WR = water requirement (mm/day) calculated from the following equation: WR = ETC- Pe – GW --------- (4)

Where: ETC = crop evapotranspiration (mm), Pe = effective rainfall (mm), GW = ground water contribution (mm).
The evapotranspiration of the date palm was calculated by the following equation:

$$ETc = ETo \times Kc \text{ ---------- } (5)$$

Where: ET_C= palm evapotranspiration ($mm.day^{-1}$), ET_O= crop reference evapotranspiration ($mm.day^{-1}$). KC= Yield coefficient, for palm ranges from 0.9 to 0.95 depending on the growing season (Allen et al., 1998).
The net irrigation needs were calculated from the following equation:
IRn = ETc - (Pe + Ge + Wb) + LR ----- (6)
IRn = Net Irrigation (mm), Pe = Effective Rainfall (mm), Ge = Contribution of Ground Water (mm), Wb = Amount of Water Stored at the Beginning of Each Period (mm).
The percentage of evaporation area (Se) from the actual shaded area during June noon (representing the maximum net solar radiation time) to the actual area of each tree was calculated from the following equation (AL-Omran et al. 2019)

$$Se = \frac{Shaded\ area\ per\ tree}{Actule\ area} * \cancel{100}\frac{\pi R^2}{6*6} * 100 \text{ --------- } (7)$$

Where: Se = percentage of evaporation area, R = tree radius (m),
Shaded area per tree = Shaded area per tree measured at noon.
Actual area = the real area and represents the product of the distance between the palms and the distance between the palm lines.
Leaching requirements (LR) were determined using the following Leaching equation (Ayers and Westcot, 1985):

$$LR = \frac{ECiw}{5\ ECe - ECiw} \text{ ------- } (8)$$

LR= Leaching requirements, ECe= the electrical conductivity of the saturated soil paste ($dS.m^{-1}$) at 25°C, which decreases the plant production by an acceptable rate, and it was estimated for palms 6.8 ($dS.m^{-1}$), where the palm production is 90% or the yield decreases by 10% (Ayers and Westcot, 1985), ECiw = electrical conductivity of irrigation water ($dS.m^{-1}$) at 25°C

Gross irrigation water was calculated according to the following equation (AL-Omran et al.2019).

$$GWR = \frac{ETc * Se}{(1 - LR) * EFir} \text{--------- (9)}$$

GWR = Gross Water Requirement (mm), Efir = Irrigation Efficiency= 85% for Bubble Irrigation System.

1-8 Water productivity

The crop's water productivity was calculated for each experimental unit on the basis of production and volume of water used during the whole season (Kambou et al., 2014). According to the following equation:

$$cwp = \frac{Y}{wu} \quad \text{------- (10)}$$

CWP = Crop water productivity ($kg.\ m^{-3}$), Y = annual production quantity of the palm (kg), WU = volume of annual water used for the palm (m^3).

Frond length increase: The length of three fronds of the second row of fronds on the palm tree was measured at the beginning of the experiment and the end of the two growing seasons for each experimental unit separately, then the average length of the fronds was taken in centimeters and then according to the annual increase in the length of the fronds, through the following equation:

Annual Frond length increase = Length at the end- Length at the beginning --- (11)

The amount of yield was calculated for the experimental units for each treatment immediately after cutting the cluster and using a field balance, where by the clusters of each replicate were weighed separately (in kilograms).

The data for the different traits were statistically analyzed using the SPSS statistical program to analyze the variance between the transactions, their differences and their interactions, using the F-test and the value of the least significant difference Revised least significant difference (RLSD) under the 0.05 level to compare the means (Al-Rawi and Khalaf Allah, 1980).

3- Results and discussion

1-3 Irrigation water requirement

Figure 1 shows the irrigation interval applied in the experiment as an average for each month depending on soil moisture depletion and daily water consumption. It is noted that the irrigations diverge in the winter months, reaching the largest irrigation interval during the month of January, and its value is (25, 28, 34) days for the soil moisture depletion treatments (30, 40, 50) % respectively, and its convergence in the summer months, where it reached the lowest irrigation interval in June and July (3, 4, and 5) days respectively,

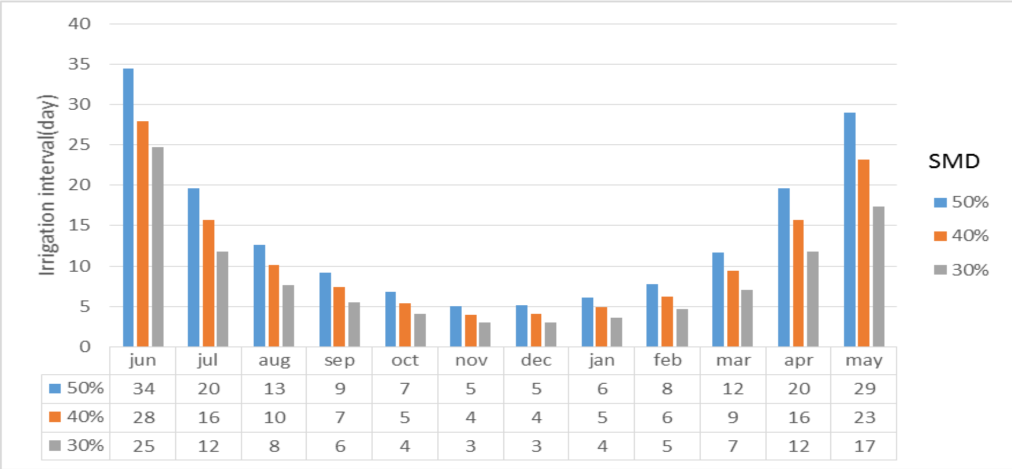

Figure (1) Irrigation interval per day for each month based on the percentage of soil moisture depletion from the effective root zone.

and this difference in the irrigation interval between the months of the year is attributed to the difference in the value of net water consumption as a result of the different climatic elements, As for the irrigation depth calculated from the soil constants for the study site and for the effective root depth of the palms, it was 50, 66, and 83 for soil moisture depletion treatments respectively, It is noted that the irrigation interval depends largely on the value of crop evapotranspiration. The effective root depth, in addition to the percent soil moisture depletion (Allen et al. 1998).

It is noted from Figure (2) that the SMD treatments had a significant effect, as the decrease of SMD in the treatment of 30% of the total available water (TAW) led to an increase in the weight of the total yield in the date palm cultivar Al-Sayer in the date stage compared to the depletion treatments 40% and 50%, as the average, The yield 34.2 and 37.2 kg.palm^{-1} for the seasons 2019 and 2020 respectively, followed by the two treatments 40%, 50% where the values were 25.3, 23.5 kg.palm^{-1} and 30.7, 28.7 kg.palm^{-1} for the two seasons, respectively. These results agree with El-Kosary, et al. (2009), where he showed in a study he conducted for the effect of three moisture depletion rates 25%, 50%, 75% on the productivity of palm fruits that the irrigation treatment when 25% of the total available water was depleted gave the best yield, Total in the two seasons, followed by 50% and 75% depletion. the reason for the superiority of 30% depletion treatment over the two treatments 40% and 50% may be due to the maintenance of soil moisture to levels that are readily available for trees and do not suffer from moisture stress, unlike the rest of the treatments, the moisture in the soil may drop to levels that may need energy More water absorption (Al-Uqabi, 2015) In addition to keeping the soil moist, leads to an increase in the activity of soil Biology, and thus an increase in soil An organic substance that helps provide nutrients and increase the ability of soil to retain water (Al-Mansor and Thaher, 2021).

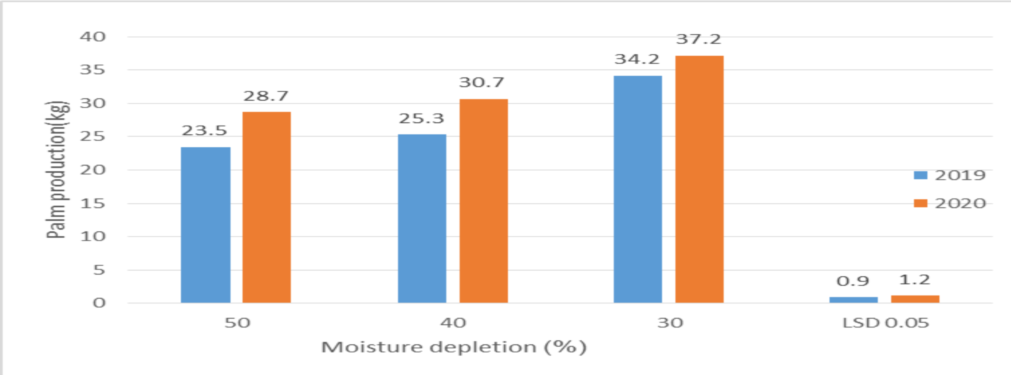

Figure (2) Effect of moisture depletion factors on the yield of Al-Sayer cultivar date palm during the date stage (kg.palm^{-1}).

It is noted from Figure (3) that the moisture depletion treatments had a significant effect, as the decrease in the 30% treatment led to an increase in the annual growth of the fronds compared to the 40% and 50% depletion treatments, which was 26.40, 20.20 $cm.year^{-1}$, for the two seasons 2019 and 2020 respectively, followed by the two treatments 40% and 50% where the values were 16.60 and 15.73 $cm.year^{-1}$, 20.07 and 19.47 $cm.year^{-1}$ for the two seasons respectively, the reason of superiority 30% depletion treatment may be due to the retention of soil moisture to levels that are readily available and Trees do not suffer from moisture stress, anther treatments, Soil moisture may decrease to levels that may need more energy to absorb water, and this is consistent with Al-Uqabi (2015) in a study he conducted on the average length of cultivated shoots where treatment of soil moisture depletion 50% significantly outperformed compared to 75% of the total available water. In addition to the increase in the number of irrigations during the growing season and the accompanying processes of washing salts downward and towards the hydration front away from the root system and the accompanying improvement in the physical and moisture properties of the soil and a decrease in its salt content, which leads to an improvement in the growth of fronds and this was confirmed by Al-Hamad and Al-Maliki (2016), where he mentioned that the response of palm trees in growth to the close irrigation interval for its role in increasing the availability of water and reducing the salinity of the soil sector.

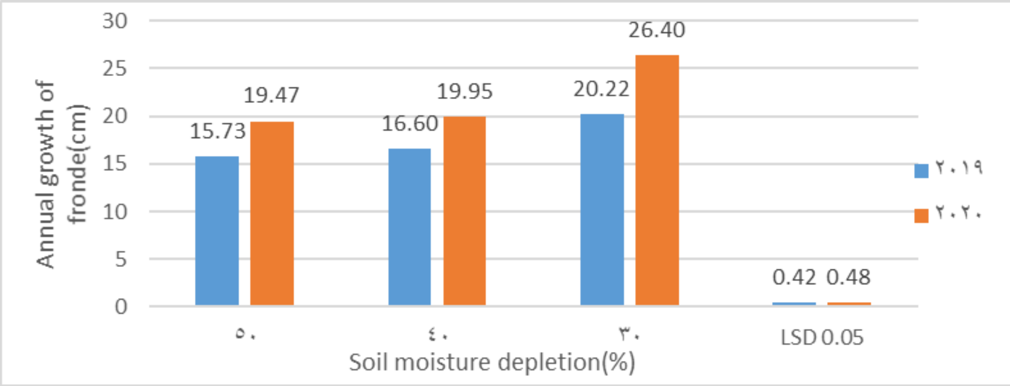

Figure (3) the effect of soil moisture depletion on the annual growth of fronds (cm) for the two seasons 2019 and 2020.

It is noted from Figure (4) that the soil moisture depletion treatments had a significant effect, as the decrease in the moisture depletion in the treatment of 30% of TAW led to an increase in water productivity, as the water productivity reached 0.53, 0.49 kg.m-3 for the 2019 and 2020 seasons, respectively, and that Because of the increase in the total weight of the date yield compared to the depletion factors 40 and 50% of TAW, the values were 0.37, 0.35 kg.m-3 and 0.45, 0.43 kg.m-3 for the two seasons, respectively, and these results agree with El-Kosary et al. (2009) Where he explained in a study he conducted the effect of three moisture depletion rates 25%, 50%, 75% on the water productivity of date palms, where the irrigation treatment when 25% of TAW was depleted gave the best water productivity and a total return in the two seasons, followed by the depletion of 50% and 75%.

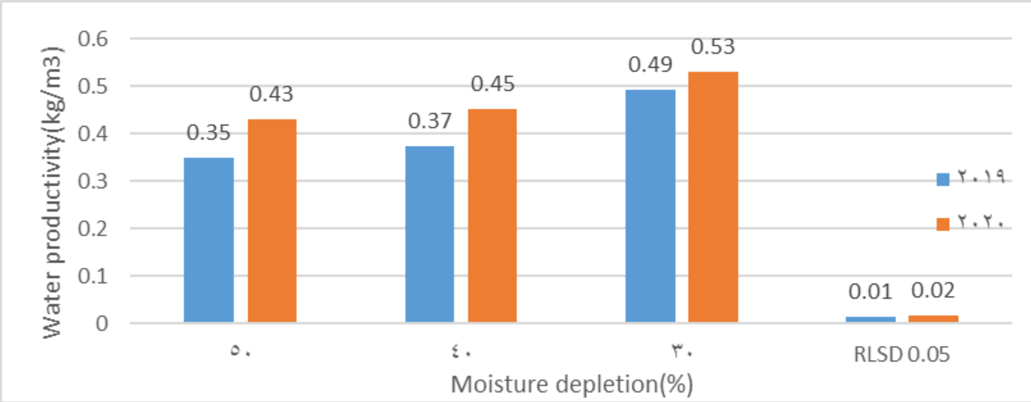

Figure (4) Effect of soil moisture depletion factors on water productivity (kg. m^{-3}).

4 conclusions:

In dry areas and due to climate change, the problem of water scarcity has become more prevalent, so the trend must be to increase water productivity. Although the date palm has the ability to withstand water stress, it negatively affects growth, total production and water productivity. The analysis of variance showed that the depletion of soil moisture significantly ($P < 0.05$) affects the yield, annual growth of fronds and water productivity, and it is noted from the results that there is a significant difference in the irrigation interval between months of the year due to the difference in net water consumption due to the different climatic elements. Irrigation at SMD 30% is recommended to achieve the highest water productivity and yield, further research is recommended in the field of SMD for palms.

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