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Effects Of Regulated Deficit Irrigation On Water Productivity Of Date Palm (Phoenix Dactylifera L.) In The Arid Environment Of South Iraq

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Abstract

Due to the scarcity of water resources in southern Iraq, the use of deficit irrigation scheduling is beneficial for sustainable agricultural development. Therefore, a two-year field experiment was conducted to study the effect of regulated deficit irrigation (RDI) on yield and water productivity (WP) of date palms irrigated with a bubbler irrigation system. Five water systems were used D1, D2, D3, D4, and FI representing 0, 25, 50, 75, and 100% of ETc and applied during two stages: the first stage includes flowering and hababouk, the second stage is the Rutub and Tamer stage they were studied to select the best water system that maximizes yield and WP, the results indicate that RDI strategies saved irrigation water by 5-39%. The highest yield was under full irrigation (FI) and (D4) and as an overall average for the two seasons, at

35.1, 35.2 kg.palm^{-1}. The largest decrease in production was recorded in the treatment of D1 by 29% compared to (FI). The highest WP was achieved in treatments D1 and D4, as an overall average for the two seasons, at 0.46 and 0.47 kg.m^{-3}. In conclusion, the palm needs regular irrigation during the year to maintain growth and production, with the possibility of reducing irrigation in the stage of flowering and hababouk and, the Rutub and Tamer. Full irrigation is recommended to achieve the highest yield, and it is also recommended to use the RDI strategy with 0-75% ETc if we consider the benefits of Economic and WP in the study area. Further research in the field of RDI is also recommended to study its effect on the phenological stages of palms.

Key words: regulated deficit irrigation, water productivity, date palm, water scarcity

1-Introduction

The Arab region, including Iraq, is considered one of the regions most affected by climate change due to the scarcity of water in it, and it is the highest in the world (Elasha, 2010). The agricultural sector is the main sector in water consumption in Iraq 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). Deficit irrigation (DI) has been extensively studied as a valuable and sustainable production strategy in dry areas by applying water shortage to growth stages. One of the objectives of this practice is to maximize water productivity and stabilize rather than increase production (Geerts and Raes, 2009). Al-Mansor et al. (2015) mentioned the use of deficit irrigation reduced the amount of production, but it saved the amount of water compared to full irrigation. One of the methods used in deficit irrigation is the regulated deficit irrigation (RDI), during which there is a shortage of irrigation for a certain period and full irrigation is released for another period (Costa et al., 2007 and Rowland et al., 2012). Mattar et al. (2021) that applying deficit irrigation to palms grown in dry areas, can maximize water productivity and improve fruit quality, but negatively affect production. RDI has been applied to palms by Sabri et al. (2017) it was concluded that the RDI irrigation strategy can contribute to save water. 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). 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. FAO (2008) the (WP) for date palm of many date-producing countries, range as a general average of 0.18-0.37 $kg.m^{-3}$. As such, the objectives of this research include (a) studying the effect of RDI in the different stages of growth on WP and obtained when using bubbler irrigation (b) developing an appropriate irrigation management strategy for Al-Sayer date palm cultivar in the arid environment of the Shatt Al-Arab region, southeast of Iraq.

2- Materials and methods

2-1 study site

The experiment was conducted in the Shatt al-Arab district, Basra governorate, southern Iraq, located at latitude 30º 42' 50.0 north and longitude 47º 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		260	189	205	254.1
Clay		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

2-2 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
	°C	°C	%	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

2-3 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.

2-4 Factors of Regulated Deficit Irrigation (RDI):

Four stages have been adopted within the irrigation deficiency factors Table (3). The first stage includes flowering and hababouk, the second stage is the kimri and khalal stage, the third stage is the Rutub and Tamer stage, and the fourth stage continues from harvesting until flowering (Daoud and Ahmed, 2019).

Table (3) Distribution of RDI factors on the stages of growth and development of fruits and the period of each stage per day.

growth stage and dev. fruits	period day	Deficit irrigation factors				
		FI	D1	D2	D3	D4
Flowering and Hababouk	47	100%	0%	25%	50%	75%
kimri and khalal	75	100%	100%	100%	100%	100%
Rutub and Tamer	62	100%	0%	25%	50%	75%
harvesting until flowering	181	100%	100%	100%	100%	100%

2-5 Gross irrigation water

The evapotranspiration of the date palm was calculated by the following equation:

$$ETc = ETo \times Kc \text{-----------} (1)$$

Where:

ET_C= palm evapotranspiration (mm/day), ET_O= crop reference evapotranspiration (mm/day). 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:

$$IRn = ETc - (Pe + Ge + Wb)$$

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)

$$Se = \frac{Shaded\ area\ per\ tree}{Actule\ area} *100 \quad \text{--------- (3)}$$

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):

$$LR = \frac{ECiw}{5\ ECe - ECiw} \quad \text{------- (4)}$$

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

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

$$GWR = \frac{ETc * Se}{(1 - LR) * EFFir} \quad \text{--------- (5)}$$

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

2-6 Water savings

The water savings was determined by dividing the difference in the water using the RDI treatment by th+e total amount of water used for the full irrigation treatment. The following equation was adopted:

$$W.S = \frac{FI - DI}{FI} \quad \text{------- (6)}$$

W.S = water saving percentage (%), FI = total water used in the full irrigation treatment (m^3.palm.year^{-1}).

2-7 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:

$$CWP = \frac{Y}{WU} \quad \text{------- (7)}$$

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

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

3-1 Irrigation water requirement

Figure 1 shows the cumulative irrigation water volume for RDI factors D1, D2, D3, D4 and FI for the irrigation used in the experiment and the calculated average for the two seasons. (52 ‹61 ‹69 ‹78‹ 86) $m^3 palm^{-1} year^{-1}$ and (55 ‹62 ‹69 ‹75 ‹80) $m^3 palm^{-1} year^{-1}$ for the RDI treatments respectively, as it is noticed from the results that the lowest values are for the RDI treatments D1, followed by D2, D3, D4 and FI, respectively. This difference is attributed to the application of RDI treatments during the flowering and hababouk stage and rutub and tamer stage, with continuous irrigation for all stages of FI treatment. It is followed by D2, D3, D4 and FI, respectively. This difference is attributed to the application of deficit irrigation of the treatments during the flowering and hababouk stage, and the rutub and tamer stage, with the continuation of irrigation for all phases of the FI treatment. It is noted that the total irrigation water volume for the applied full irrigation treatment and calculated as a general average for the 2019 and 2020 seasons is (86, 80) $m^3.Palm^{-1}.year^{-1}$ respectively, and this amount is consistent with what was mentioned by Alamoud et al. (2012) as the total annual net water use in the regions of Saudi Arabia ranged between 59.4 and 108 $m^3.Palm^{-1}.year^{-1}$, according to the geographical location, climate elements and soil characteristics.

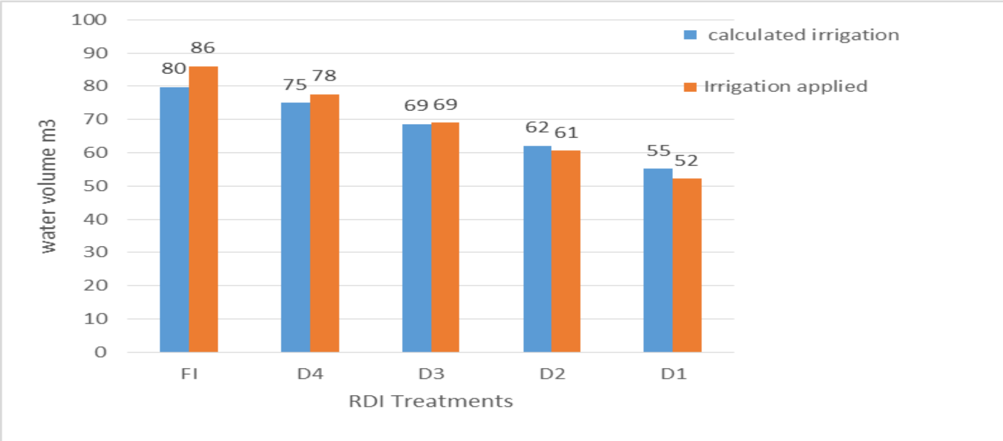

Figure: (1) The annual used irrigation water requirement, calculated as an average for two seasons, $m^3 palm^{-1}$.

Figure (A29, B29) the volume of irrigation water (m^3.palm^{-1}) during the stages of growth and development of fruits, and it represents the volume of irrigation water used and calculated as an average for two seasons. Under the experiment treatments and expressed as (m^3.Palm^{-1}) were (0.0, 2.5, 5.1, 7.6, 10.2) and (0.0, 5.8, 11.6, 17.4, 23.3) for treatments D1, D2, D3, D4 and FI, respectively. While the calculated water volume as an

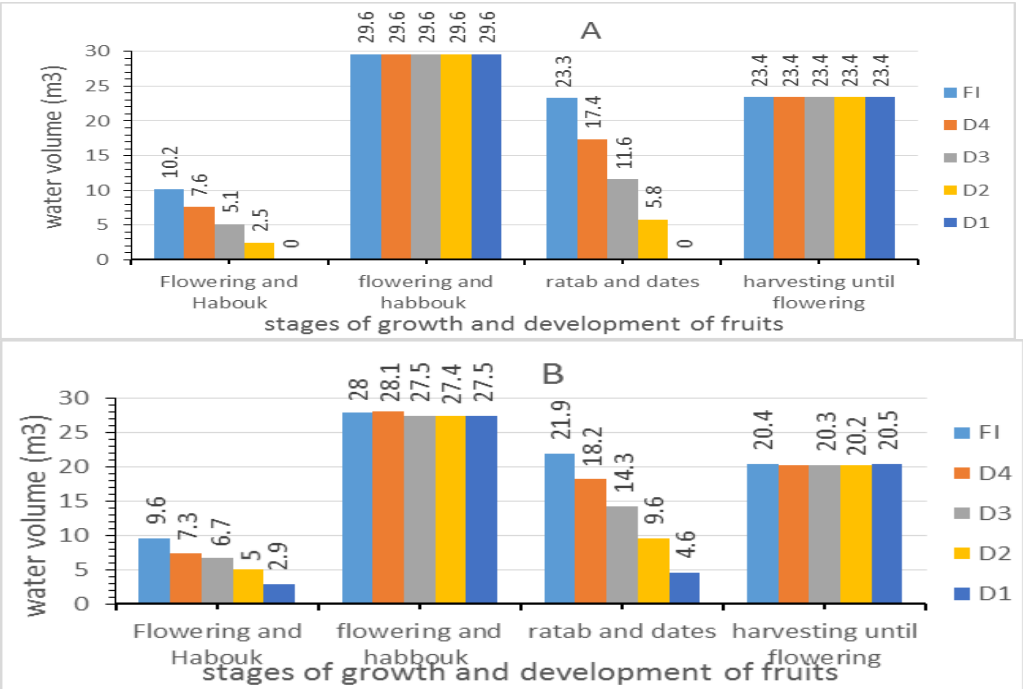

Figure (29) the volume of irrigation water as an average for two seasons (m^3 palm^{-1}) during the stages of growth and development of fruits, (A) represents the applied water and (B) the calculated water.

average for the 2019 and 2020 seasons and for the same periods and treatments, respectively (2.9, 5.0, 6.7, 7.3, 9.6) and (4.6, 9.6, 14.3, 18.2, 21.9), the volume of water applied in Experiment 29.6 and 27.7 $m^3.palm^{-1}$, respectively, for all treatments and the calculated water volume as an average for two seasons and for all treatments 27.7, 20.3, respectively. And that this increase in the volume of irrigation water of kimri and khalal stage and the stage harvesting until flowering is due to the use of full irrigation for all treatments during the two stages, where it reached 185 days.

Figure 3 shows the annual irrigation water savings ratio (%) for the RDI treatments, for the irrigation water used in the experiment for an entire season of 12 months, and the calculated water for the 2019 and 2020 seasons compared to the full irrigation treatment. The percentages of water saving for irrigation used in the experiment compared to full irrigation FI for all stages was (39, 30, 20, 10)% for treatments D1, D2, D3, D4, respectively. while the percentage of water saved for irrigation calculated for the 2019 and 2020 seasons was For the same treatments compared to FI for all stages (29, 20, 11, 5)% and (33, 25, 17, 8)% respectively, and these results are in agreement with Cui et al. (2008) where it was mentioned that all treatments of regulated deficit irrigation, saved irrigation water by 13-25% compared to the treatment of FI, also in agreement with what was found by Sabri et al. (2017) when he mentioned that it is possible to save water percentage between 19-39% by using the RDI method for the date palm.

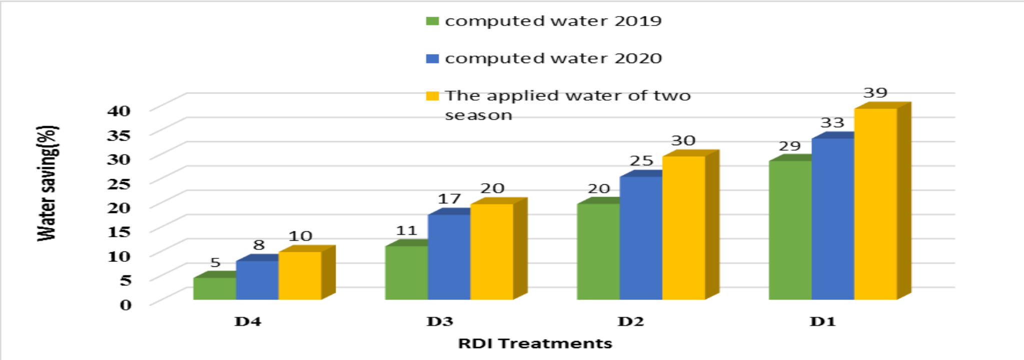

Figure (3) Annual irrigation water savings ratio (%) for the treatments of RDI for the irrigation water used in the experiment and the calculated water for the two seasons 2019 and 2020 compared to the full irrigation treatment.

3-2 the yield per tree

The results of the statistical analysis of the F-test show that there is a significant effect of the RDI factors on the average quantity of yield in the tamer stage for the 2019 and 2020 seasons. It can be seen from Figure (4) that the treatments of full irrigation (FI) and RDI, D4 were significantly superior to the other treatments and as an overall average of 32.4, 32.5 kg.palm^{-1} for the 2019 season and 37.8 and 37.9 kg.palm^{-1} for the 2020 season, while There were no significant differences between the two treatments FI and D4, as for the general average of the under RDI treatments (D1, D2, and D3) at (26.6, 23.7, 23.3) kg.palm^{-1} for the 2019 season, respectively, and (30.4, 27.7, 27.3) kg.palm^{-1} for the 2020 season, respectively, as it is noted that there are no significant differences between treatments D1 and D2 for the two seasons, but there are significant differences with treatment D3, and the reason may be due to the exposure of these two treatments to higher moisture stress than the rest of the RDI treatments. In general, it is noted that the yield decreased, and the reason may be due to the exposure of these two treatments to higher moisture stress than the rest of the RDI treatments. Treatments under study compared to the FI treatment, and that the yield decreased in the treatments from D4 to D1 for both seasons and in succession, and this is due to the amount of water used for irrigation in those treatments, accumulation of salts (Yassin et al. 2020). Higher values of the yield of the palm tree for the FI treatment are due to the high amount of used water Where 100% of the value of ETc was used for all stages of growth and development of fruits. These results are in agreement with those of Mattar et al. (2021) where he showed that DI when treating (I50) for date palm reduced production by an average of 86 kg.palm^{-1}, while the production increased under excessive irrigation (I150) to 123.25 kg.palm^{-1} and stated that the amount of yield, increases with the increase in the level of irrigation water added to the soil. The yield increase could be related to the availability of optimum soil moisture, which promotes balanced root growth and nutrient uptake (Mohammed et al. 2021). Irrigated soils suffer in arid and semi-arid regions of the world, from the problem of the accumulation of salts.

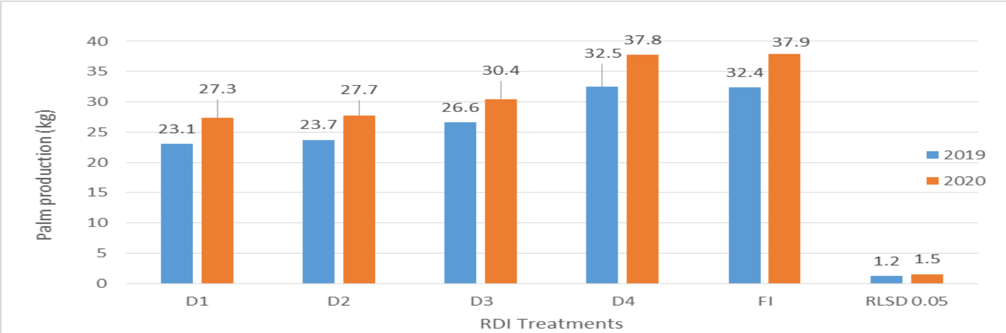

Figure (4) Effect of RDI treatments on the yield of Al-Sayer cultivar date palm during the date stage (kg.palm^{-1}).

3-3 Water Productivity (WP)

The results of the statistical analysis of the F-test show that there is a significant effect of the RDI factors on the water productivity of date palms for the 2019 and 2020 seasons. It can be seen from Figure (5) that the two treatments D1 and D4 were significantly superior to the other treatments and as a general average of 0.41 and 0.43 $kg.m^{-3}$ for the 2019 season and 0.50 and 0.50 $kg.m^{-3}$ for the 2020 season, respectively, while no It shows significant differences between treatments D1 and D4, followed by the full irrigation treatment FI, with a significant difference of 0.41 and 0.47 $kg.m^{-3}$ for the two seasons, while the general average of the RDI treatments (D2, D3) was (0.38 and 0.39) $kg.m^{-3}$ for the season. 2019, and (0.45 and 0.45) $kg.m^{-3}$ for the 2020 season, respectively, as it is noted that there are no significant differences between treatments D2 and D3 for the two seasons, and the reason for the high WP of the RDI treatment D1 is due to the use of a lower total water volume as a result of using 0% ETc water volume during deficit irrigation period. These results are in agreement with Al-Qurashi (2016) who stated that water productivity increases with the decrease in the amount of used water. As for the reason for the high value of treatment D4, it is due to the increase in the value of the total yield with the receipt of an amount of 75% of ETc during the deficit irrigation period, gave the highest average WP 0.89 $kg.m^{-3}$. Also, the increase in the WP of FI compared to treatments (D2, D3) is due to the higher yield of the full irrigation treatment FI compared to the RDI treatments, despite receiving 100% of ETc for all stages of growth and development of fruits. In general, a number of researchers stated that increase production while reducing the amount of used water to a minimum leads to an increase in the WP of palms. The reason may be the palm's ability to efficiently use water from the soil sector during water stress (Alamoud et al. 2012; Ismail et al., 2014; Sabri et al., 2017).

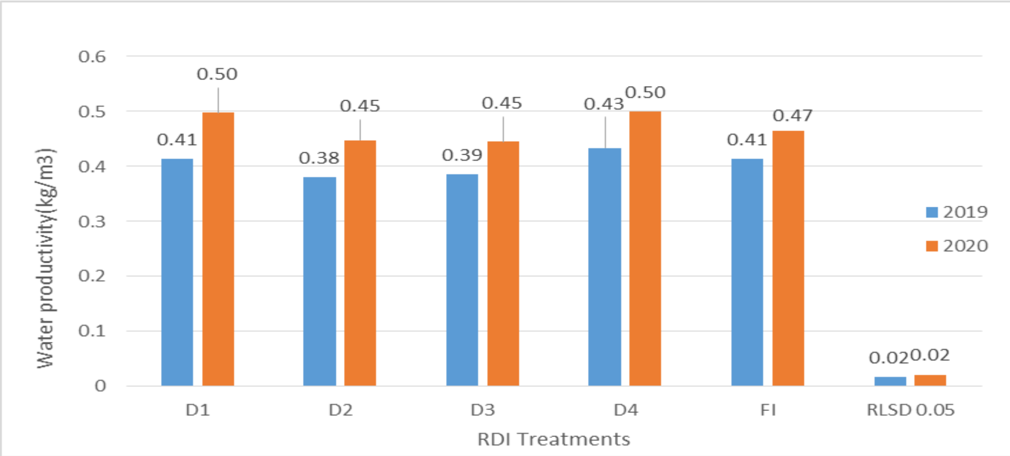

Figure (5) Effect of RDI treatments on WP (kgm^{-3}).

4 Conclusions:

In dry areas and due to climate change, the problem of water scarcity has become more prevalent. Although the date palm has the ability to withstand water stress, it negatively affects production. In order to obtain a high production, 100% of ETc is used, and the use of RDI at a rate of 0-75% of ETc during the periods from the beginning of the flowering stage to the beginning of the Kamari stage and from the end of the Khalal stage and the beginning of the rutub stage to the end of the season and harvesting of fruits can save water by 5 %-39% It is possible to achieve the highest productivity of irrigation water WP without significant losses in production when using RDI and 75% of ETc.

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