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Date Palm (*Phoenix dactylifera* L.) Irrigation Water Requirements as Affected by Salinity in Oued Righ Conditions, North Eastern Sahara, Algeria

[1,2]Mihoub Adil, [1]Helimi Samia, [1]Mokhtari Sakher, [1]Kharaz El Hafed, [1]Koull Naima, [1]Lakhdari Kawther, [1]Benzaoui Tidjani, [1]Bougafla Abdesselam, [1]Laouisset M'hamed Bensalah, [1]Kherfi Yamina and [1]Halitim Amor

[1]Scientific and Technical Research Centre for Arid Region (C.R.S.T.R.A), Biophysical Station, Nezla, 3240, Touggourt, Algeria

[2]Laboratory of Ecosystem Protection in Arid and Semi-arid Areas, University of Kasdi Merbah, Ouargla BP, 51130000, Ouargla, Algeria

Corresponding Author: Mihoub Adil, Scientific and Technical Research Centre for Arid Region (C.R.S.T.R.A), Biophysical Station, Nezla, 3240, Touggourt, Algeria Tel: +213799787008 Fax: +21333741815

ABSTRACT

A field study on a saline condition was carried out at agricultural farm of Deglet Nour date palm during the 2012 growing season. It focuses on the irrigation water management problem as affected by salinity in Oued Righ region (North Eastern Sahara, Algeria). To determine irrigation requirements a computer model based on the computation of reference evapotranspiration, crop coefficient, water holding capacity, leaching requirements and daily water use by date palm was used. The average annual amount of irrigation for a palm tree was varied from 145-218 m^3 per palm. According to the system of irrigation used, localized irrigation of one ha containing 120 palm trees at Touggourt required water on annual basis as 17411 m^3 ha^{-1} $year^{-1}$. On the other side, the use of traditional irrigation system (e.g., border irrigation) consumes more water to the tune of 26117 m^3 ha^{-1} $year^{-1}$. This model was employed to improve water management practices by the farmers. The result shows that localized irrigation will, therefore, be more efficient than non-localized one (e.g., border irrigation) and it can reduce irrigation water up to 50%.

Key words: Date palm, water requirements, salinity, irrigation system, Oued Righ, Algeria

INTRODUCTION

One of the most important factors limiting crops yields is the irrigation water; water resource management is becoming a critical issue of land management. The predicated climate changes will result in an increase in duration and intensify of summer drought. Hence, there is an urgent to improve our knowledge concerning the water use and response to drought of the main perennial vegetation types such as date palm and fruit trees (Kassem, 2007).

Date palm (*Phoenix dactylifera* L.) is one of the important and strategic fruits in Algeria. Based on FAO reports (FAO., 2012) date palm area harvested and annually date palm production in Algeria are 163985 ha and 789357 t, respectively. Among different date palm cultivars, Deglet Nour date palm is one of the most commercial and popular date cultivars in the world especially in the North of Africa.

Date palm is the most important and widely cultivated crop in Oued righ region; it consumes nearly 90% of irrigation water. Improper irrigation water management leads to some dangerous effects such as: Decline in the piezometric level of the terminal complex water (TC), disappearance of artesian and rise of groundwater and salinisation of soil.

Irrigation of sandy soils must be considered carefully. In this chapter, a review is made of the physical characteristics and water-soil relationships of sandy soils (Sanchez *et al*., 2012), as well as various irrigation systems. Recommendations are also given on proper water management at field level.

Dry land and irrigated agriculture depend on the management of two basic natural resources; soil and water. Soil is the supporting structure of plant life and water is essential to sustain plant life. The wise use of these resources requires a basic understanding of soil and water as well as the crop itself.

Irrigating sandy soils requires high attention to the timing and amount of irrigation water applied (Sanchez *et al*., 2012), which are crucial decisions for each operator. Applying too much water means increased pumping costs, reduced water efficiency and increased potential for pollutant leaching below the rooting zone and into the ground water. Delaying irrigation until plant stress is evident can result in economic yield loss (Alhammadi and Al-Shrouf, 2013).

Irrigation Water Management is the process of determining and controlling the volume, frequency and application rate of irrigation water in a planned (Thompson *et al*., 2007). With a good irrigation management we can: "maximize net return, minimize irrigation cost, maximize obtained yield, optimally distribute a limited water supply and minimize ground water pollution". To achieve these goals, it is necessary to schedule irrigation (Huygen *et al*., 1995).

The present study aims to determine water requirements of date palm grown in a saline environment and adopt an appropriate irrigation scheduling method in Oued Righ conditions could lead to increase in yield, significant water saving, reduce environmental impact of irrigation and improve sustainability of irrigated agriculture.

MATERIALS AND METHODS

Study area: The region of Oued Righ is a geographical entity situated in South-Eastern of Algeria between latitude from 32°54' to 39°9' North and longitude from 05°50' to 05°75'. The bottom of the region is a long depression (150 km length, 20 km wide) (Kouzmine, 2003). It occupies of surface of 1874 km^2, represents 8 communes administratively and includes a number of populations of 200916 inhabitants. The valley Oued stretches over 150 km long and 20-30 km wide, between El Goug and Oum El Thiour (Tesco, 1989).

Meteorological data: The climate is hot and dry in summer, cool and wet in winter. The average annual precipitation is 57 mm (Table 1). Between May and September the average daily maximum temperature more than 40°C. In July and August intense daytime heat is mitigated by low relative humidity (10-50%) and in winter the average daytime temperature is in the low 10°C (Fig. 1). Therefore, very low and erratic rainfall, there is no precipitation in summer. In spring and early summer the wind prevails.

Hydrology data of studied area: The region of Chott Merouane and Chott Melghir is the natural outlet of these hydraulic complexes (Nesson, 1978) (Fig. 2).

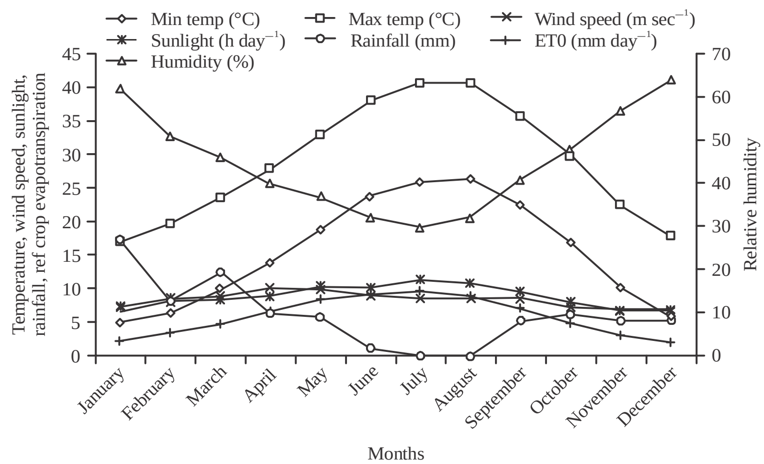

Fig. 1: Scheme of Touggourt climate

Table 1: Climatic conditions in Oued Righ valley

Month	Minimum temperature (°C)	Maximum temperature (°C)	Humidity (%)	Wind speed (m sec^{-1})	Sunshine (h)	Rainfall (mm)	ET_0 (mm day^{-1})
January	5.0	17.1	62	7.20	6.6	17.20	2.18
February	6.4	19.7	51	8.48	8.2	8.12	3.27
March	10.0	23.6	46	8.95	8.5	12.40	4.77
April	13.9	28.0	40	10.07	9.0	6.30	6.65
May	18.8	33.0	37	9.94	10.3	5.80	8.34
June	23.8	38.1	32	9.09	10.1	1.20	9.45
July	26.0	40.8	30	8.60	11.4	0.00	9.67
August	26.3	40.8	32	8.53	10.9	0.00	8.86
September	22.5	35.8	41	8.54	9.6	5.20	6.99
October	16.8	29.9	48	7.05	7.9	6.20	4.73
November	10.1	22.6	57	6.71	6.6	5.20	2.93
December	5.8	17.9	64	6.72	6.6	5.40	2.01

Quaternary aquifer (phreatic aquifer): This aquifer consists of sand more or less fine clay and gypsum. The substrate is formed of clay simultaneously forming the roof of the first layer of (TC). Its average thickness is 7-60 m. This table is no longer operated because of the high salinity. This layer is supplied mainly by water seepage from rivers and especially by surplus water percolation during irrigation periods.

Terminal Complex aquifer (TC): Is localized in the Western Sahara and extends an area of 350.000 km^2 with a depth between 100 and 500 m; their water characterized by: A low temperature, low salinity on the borders and relatively high in the center (over 3 g L^{-1}). This table includes two aquifer systems called sandy and limestone aquifer.

Intercalary Continental aquifer (IC): Often called "Albian water", consists mainly of post-Paleozoic sediments ranging from Triassic to the Albian and represented by alternating of sandstone and clay layers or permeable levels are dominant with a thickness of above 250 m and sometimes reaching over 1000 m. These water are characterized by: A temperature which exceeds 50°C. The mineralization of the water is between 1 and 2 g L^{-1} of dry residue.

Field experiment area: This study was conducted at the farm of date palm tree in Touggourt, Top of Oued Righ valley during 2012 season. The geographical location of the farm is 33°3'N

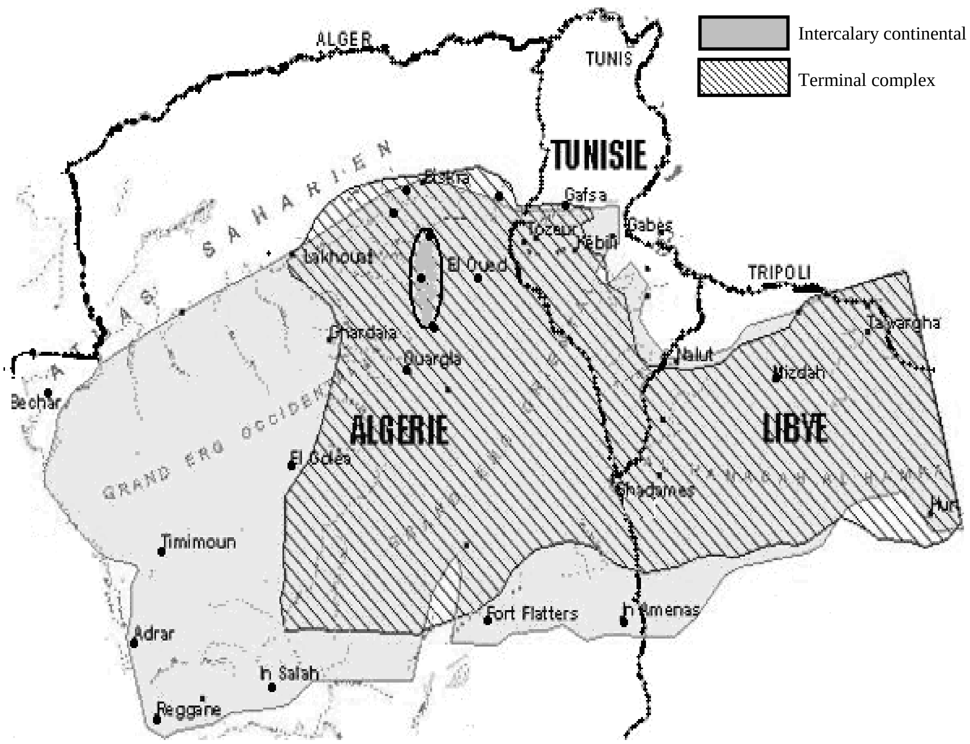

Fig. 2: Ground water resources in Oued Righ Valley: TC and IC aquifer (UNESCO., 1972)

latitude, 6°1'E longitude and 85 m altitude. Field measurements were taken during the productive cycle of 15 years old date palm tree ‘Deglet Nour’ variety from 09/05/2013 to 09/05/2014. In One hectare 120 of date palm grown and spaced of 9.0 m between rows by 9.0 m between trees. The date palm tree had an average height of trunk 2.5 m; average diameter of trunk 80 cm. in the case of our field experiment two irrigation systems were applied by the farmer to irrigate date palm trees, Localized and border irrigation system were used to irrigate the field, for localized irrigation each date palm tree was irrigated by a lateral line around the tree and the distance between the lateral line and the date palm trunk was 0.8 m. One emitter was used to irrigate the date palm tree. In the case of border irrigation, the border had a length of 100 m and a diameter of 1.5 m.

Soil sampling and analysis: Before beginning the experimental work, the bulk sample of soil was collected using an auger, at depth of at depth of 0-20, 20-40, 40-60 and 60-80 cm at five sampling points randomly selected along agricultural farm. The collected samples were air dried, crushed, sieved through a 2 mm sieve and stored for chemical characteristics determination. Routine analysis of the tested soil was determined according to the standard methods published by Richards (1954) and Jackson (1958). A Richard’s pressure chamber was used for determining soil water retention for pressure of 0.33 and 15 bar. Electrical Conductivity (EC) was measured using IMKO’s TRIME TDR.

Calculation procedure

Reference crop evapotranspiration (ET_0): It was determined by Penman-Monteith equation (Allen *et al*., 1994) using Cropwat 8.0 computer program. Cropwat 8 is a computer program based on the revised Penman-Monteith method, to calculate crop water requirements (Smith, 1992).

Crop coefficient (Kc): Crop coefficient is mainly controlled by the crop characteristics namely the resistance to transpiration of different plants. To maintain good growth and yields of good quality a regular water supply is needed throughout the year with a possible exception just prior and during harvest and at winter time. The adjusted crop coefficient was determined by the following equation (Hess, 1996):

$$Kcadj = (Kcb \times KS) + Ke$$

where, Kcb is basal crop coefficient when the water is not a limiting factor for plant growth, Kcb is set equal to 0.8 (Doorenbos and Pruitt, 1977), KS is water availability factor [0-1]. Calculated KS was equal to 1 (Jan-March), 0.96 (April-mid May) and 1 (mid May-December), Ke is water evaporation coefficient, Ke was equal to 0.3 (Awadiss *et al*., 2005).

Actual crop evapotranspiration (ETa): Precipitation and irrigation amounts are often not sufficient to supply the full ETc requirement. In these situations, soil water content in the root zone is reduced to levels too low to permit plant roots to extract the full ETc amount. Under these conditions, water stress is said to occur and ETa is less than ETc. The reduction in ETa can be estimated using a daily soil water balance, as follows. It was estimated using modified Penman (Doorenbos and Pruitt, 1977) instead of Penman-Monteith equation (Allen *et al*., 1994). In the case of our study computer software: Cropwat8.0 was used to calculate Reference crop evapotranspiration (ET_0). The daily water use by palm tree is calculated as follow:

$$ETa = (Kcadj \times ET_0) \times Kr \times Ar$$

where, ETa is crop evapotranspiration or crop water requirement (mm day^{-1}), ET_0 is reference crop evapotranspiration (mm), Kr is Ground cover reduction factor Kr, The calculated Kr is equal to 0.7. Ar is area covered for each palm, is equal to 28 m^2 for date palm (10 years and older) (Liebenberg and Zaid, 1999) and Kcadj: Adjusted crop coefficient.

Water Holding Capacity (WHC): The total available soil water of the soil is defined as the amount of soil water content held between Field Capacity (FC) and the Wilting Point (PWP). It is determined as follow:

$$WHC = TAW \times 10 \times Pd \times Zr$$

where, WHC is water holding capacity (mm m^{-1}), TAW is available soil water in the root zone = (FC-PWP) (%), Pd is bulk density (g cm^{-3}) and Zr is Effective rooting depth (m).

Readily Available Water (RAW): Although water is theoretically available until wilting point, crop water uptake is reduced well before wilting point is reached. Where the soil is sufficiently wet, the soil supplies water fast enough to meet the atmospheric demand of the crop and water uptake equals ETc. The fraction of TAW that a crop can extract from the root zone without suffering water stress is the readily available soil water:

$$RAW = p \times WHC$$

where, RAW is readily available soil water in the root zone (mm), p is extraction allowed fraction, to ensure that the palm will not be put under water stress, it is the normal practice to allow for only a fraction of the available water to be extracted. For date palm, as illustrated below, this fraction equals 0.5 or 50% of the available soil water (FAO-56).

Leaching Requirements (LR): Palm irrigated with water having a high salt content must necessarily be drained, so that the accumulation of salt in the soil renders it not sterile (Munier, 1973).

The minimum amount of water required to remove salts from the root zone area was estimated using a standard leaching formula. For example, the FAO-29 leaching equation:

$$LR = \frac{E_{Ciw}}{5\ E_{Ce} - E_{Ciw}}$$

where, Ece is electrical conductivity of the saturation extract of the soil reported in dS m^{-1} at 25°C. For date palm trees is equal to 6.8 dS m^{-1} at 90% yield potential or 10% yield reduction (Ayers and Westcot, 1976). Eciw is Electrical conductivity of the irrigation water in dS m^{-1} at 25°C. In this study was equal to 7.59 dS m^{-1}. The obtained Leeching Fraction (LR) with applying this formula was 28.74%.

Net Irrigation Requirement (NIR): FAO (1984) defines the net irrigation requirements as the depth or volume of water required for normal crop production over the whole cropped area, excluding contribution from other sources. The net irrigation requirement was then calculated from the following equation:

$$NIR = \frac{ET_a}{1\text{-}LF}$$

where, NIR is net irrigation requirement (liter), LR is leaching requirement.

Gross Irrigation Requirement (GIR): The gross irrigation requirements account for losses of water incurred during conveyance and application to the field.

To calculate the gross amount of the applied water (GIR), it is necessary to know the Application Efficiency (AF) of the irrigation system. The application efficiency includes both distribution uniformity and uniformity coefficient, as shown below:

$$GIR = \frac{NIR}{W \times UC}$$

where, GIR is gross irrigation requirements (mm $year^{-1}$), E is application efficiency of the irrigation system was equal to 90 and 60%, for localized and border irrigation system, respectively, UC is uniformity coefficient; the calculated UC was equal to 58%.

RESULTS AND DISCUSSION

The irrigation water was obtained from the terminal complex table. The irrigation water has a pH of 7.14 and an electrical conductivity of 7.59 dS m^{-1}. Sodium Adsorption Ration (SAR)

Table 2: Chemical composition of irrigation water and electrical conductivity

Parameters	Values
pH	7.14
EC (dS m^{-1})	7.59
Ca^{+2} (mmol L^{-1})	27.00
Mg^{+2} (mmol L^{-1})	15.90
K^{+} (mmol L^{-1})	0.95
Na^{+} (mmol L^{-1})	6.39
Cl^{-} (mmol L^{-1})	20.00
$SO_{4\text{-}2}$ (mmol L^{-1})	28.49
HCO_3^{-} (mmol L^{-1})	2.38

EC: Electrical conductivity

Table 3: Some important proprieties of soil

	Mechanical analysis (%)									
Soil depth (cm)	Sand	Silt	Clay	Bulk density (g cm^{-3})	Field capacity (%)	Wilting point (%)	Water holding capacity (mm m^{-1})	EC (dS m^{-1})	pH (1:2.5)	Gypsum (%)
0-20	76.45	20.00	3.55	1.34	15.60	9.27	84.82	3.34	7.83	19.53
20-40	77.56	14.97	7.47	1.31	15.32	8.53	88.95	3.73	7.86	24.13
40-60	81.29	14.59	4.12	1.45	15.50	9.00	94.25	3.48	7.91	21.56
60-80	71.77	18.58	9.65	1.36	15.06	9.59	74.39	3.56	7.89	20.64
Mean	76.77	17.04	6.20	1.37	15.37	9.10	85.60	3.53	7.87	21.46

EC: Electrical conductivity

Table 4: Monthly actual evapotranspiration by Deglet Nour date palm at Touggourt (Top of Oued Righ Valley), Algeria

Months	ETa (mm $month^{-1}$)
January	1601.30
February	2232.31
March	3745.63
April	5147.89
May	6782.41
June	7472.97
July	7889.36
August	7162.13
September	5177.45
October	3498.49
November	2012.41
December	1454.37
Annual consumption	54176.72

Eta: Crop evaporation or crop water requirement

value was 1.38 (Table 2). The soil of the field site is classified as gypsum sandy soil with groundwater table with about 1 m of depth and is saline in nature having EC as 3.53 dS m^{-1} (Table 3).

Daily water use by date palm: Table 4 shows that mean actual evapotranspiration rates varied between 1.76 mm day^{-1} (winter) and 6.75 mm day^{-1} in summer period.

The Saharan zone is characterized by an arid climate therefore, very low and erratic rainfall; the practice of agriculture in this zone is thus possible only using the irrigation. The crop water requirements are closely related on the climatic conditions in particular the evapotranspiration but also to the nature of the soil and the growing stages of the crop. In the winter period (December, January and February) the climatic demand is low and during this time the palm tree is in very slow growth, so the water requirements was lowest.

To date palm, water requirements are particularly important. Indeed, it requires for its growth, development and fruiting, large quantities of water are of the order of 2400 kg of water to produce one kilogram of dates (Djerbi, 1994).

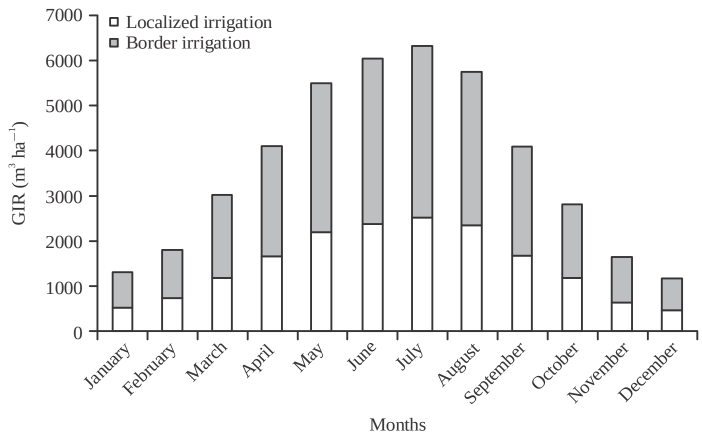

Fig. 3: Gross Applications for different systems during the year

Table 5: Net and gross irrigation applications for different irrigation systems at Touggourt (Top of Oued Righ Valley), Algeria

		Gross applications for different systems			
		Localized irrigation		Border irrigation	
Month	NIR (m^3 per palm)	m^3 per palm	m^3 ha^{-1}	m^3 per palm	m^3 ha^{-1}
January	2.24	4.29	514.63	6.43	771.94
February	3.12	5.98	717.43	8.97	1076.14
March	5.24	10.03	1203.78	15.05	1805.67
April	7.20	13.79	1654.44	20.68	2481.67
May	9.48	18.16	2179.75	27.25	3269.63
June	10.45	20.01	2401.68	30.02	3602.52
July	11.03	21.13	2535.50	31.69	3803.25
August	10.01	19.18	2301.79	28.77	3452.68
September	7.24	13.87	1663.94	20.80	2495.92
October	4.89	9.37	1124.35	14.05	1686.53
November	2.81	5.39	646.75	8.08	970.13
December	2.03	3.90	467.41	5.84	701.11
Annual application	75.74	145.10	17411.46	217.64	26117.19

NIR: Net irrigation requirement

Table 6: Approximate water requirements of date palm

References	No. of palm per ha	Approximate requirements (m^3 ha^{-1} $year^{-1}$)
Rolland (1894)	120	34190
Reme (1935)	120	17940
Gautier (1935)	129	33927
Wertheimer (1954)	120	26040
Monciero (1961)	123	26383
Sogeta (1971)	120	30000
Toutai (1979)	120	28000
Dubost (1991)	120	16000
Awadiss *et al.* (2005)	120	21279

The water requirement of date palm was in minimum in December. On the other side, at July the amounts of irrigation are in maximum with an amount of 2535 m^3 ha^{-1} for the localized system and 3803 m^3 ha^{-1} in the case of border irrigation system (Fig. 3).

Table 5 shows differences in summer and winter requirements in the studied region. For example in the case of localized irrigation summer water requirements (July, August and

Table 7: Irrigation intervals and number of irrigation applications over the growing season of date palm at Touggourt (Algeria)

Months	No. of days	ET_{crop}	Irrigation interval (days)	No. of irrigations per month	GIR (m^3 per irrigation)	
					Localized system	Border system
January	31	2.80	31	1	514.63	771.94
February	28	4.07	21	1	717.43	1076.14
March	31	6.16	14	2	601.89	902.84
April	30	8.75	10	3	551.48	827.22
May	31	9.54	9	3	726.58	1089.88
June	30	11.58	7	4	600.42	900.63
July	31	12.15	7	4	633.88	950.81
August	31	11.80	7	4	575.45	863.17
September	30	8.81	10	3	554.65	831.97
October	31	5.76	15	2	562.18	843.27
November	30	3.42	25	1	646.75	970.13
December	31	2.96	29	1	467.41	701.11
No. of irrigations per year	29					

GIR: Gross irrigation requirements

September) are about 6501 m^3 ha^{-1} while, only 1699 m^3 ha^{-1} are needed for the winter period (December, January and February). Summer requirements are almost high the winter ones and constitute one-third of the total annual consumption.

Indeed, the average annual amount of irrigation for a palm tree is varied from 145-218 m^3 per palm (Table 5). According to the system of irrigation used, the localized irrigation of one ha containing 120 palm trees at Touggourt that requires a water annual of about 17411 m^3 ha^{-1} $year^{-1}$(0.55 L/s/year). On the other side, the use of the system of traditional irrigation (e.g., border irrigation) consumes more water whose amounts are estimated at 26117 m^3 ha^{-1} $year^{-1}$ (0.83 L/s/year). Of this fact localized irrigation will therefore be more efficient than non-localized one (e.g., flood irrigation). It can reduce up to 50% of the irrigation water.

There are several studies and experiments have been done and focused on the need for water palm, various authors' stated annual volume of irrigation water for one hectare of date palm trees (Table 6).

Irrigation scheduling: As the demand for water increases, along with the need to protect aquatic habitats, water conservation practices for irrigation need to be effective and affordable. Precision irrigation will optimize irrigation by minimizing the waste of water and energy while maximizing crop yields (Ahmadi *et al*., 2010).

The most effective method for determining the water demands of crops is based on the real time monitoring of soil moisture and direct water application used in conjunction with the information about soil hydrological properties and evapotranspiration (Laboski *et al*., 2001).

Good irrigation scheduling means applying the right amount of water at the right time. In other words, making sure water is available when the crop needs it. Scheduling maximizes irrigation efficiency by minimizing runoff and percolation losses. This often results in lower energy and water use and optimum crop yields but it can result in increased energy and water use in situations where water is not being managed properly.

Once it is known how much water to apply, it is also important to know when to apply it. To determine this, knowledge of the type of soil and how deep it is, is required. This gives an indication

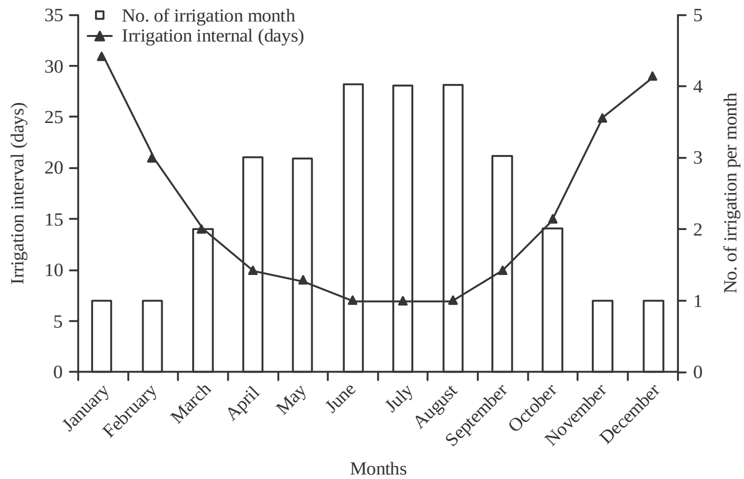

Fig. 4: Evolution of irrigation intervals and number of irrigation applications during the year

of how much water is in the soil and how much is available for the palm. This information, combined with the daily usage of water by the palm, enables the determination of when the next irrigation cycle is due. For example, the water usage of date palm in April period is 8.75 mm day^{-1} (Table 7). Table 2 shows that the available water for the soil is 85.6 mm m^{-1} depth. The rooting depth of a full grown date palm is 2 m. Thus:

$$\text{Available water} = 2\times85.6 = 171.2 \text{ mm}$$

$$\text{Extraction allowed (p)} = 0.5\times171.2 = 85.6 \text{ mm}$$

Thus, the irrigation interval was 85.6÷8.75 = 9.78 days. 10 days (Practically).

In medium soil, irrigate every three to six days in summer and every ten to fifteen days in winter (Toutai, 1979). In the case of this study, the average of irrigation interval was varied between 8 days with an average of four irrigation per month (in summer) and 27 days with one irrigations per months (in winter) (Fig. 4).

CONCLUSION

The objective of this study was to determine the water requirements throughout the productive cycle of a date palm tree Deglet Nour variety, by a model based on the computation of some climatic, soil and crop parameters. In Touggourt (North Eastern Sahara, Algeria), mean actual evapotranspiration rates varied between 1.76 mm day^{-1} (Winter) and 6.75 mm day^{-1} (Summer), between winter and summer periods the gross water requirements of Deglet Nour date palm were varied from 3.9-21.13 m^3 per palm and from 5.84-31.69 m^3 per palm for localized and border irrigation system, respectively. Of this fact localized irrigation will therefore, be more efficient than non-localized one. It can reduce up to 50% of the irrigation water quantities. Farmers should be encouraged by governments to use localized irrigation methods as a means of saving water. Since, water is a scarce resource in the North Africa region, research should focus on developing ways to improve the water productivity of this high value crop.

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