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Estimation of Water Requirements for Young Date Palms Under Arid Climatic Conditions of Kuwait

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Abstract: Date palm (*Pheonix dactylifera* L.) is one of the only a few crops adapted to Kuwait's extremely hot and dry weather conditions of Kuwait. The crop water use during different developmental stages depends on evapotranspiration (ET) rate at that particular period. A study using one year old plants of three tissue-cultured cultivars of date palms was conducted in 2008 to determine actual water requirements under Kuwait's environmental condition. Fifty plants of each of the three varieties, namely Khalas, Siwi and Nabusaif were used in this study. A total of 33 drainage lysimeters were installed (ten in each of the three varieties and three in *Phasphalum viginatum* grass) was used. The Sentek (Sentek Sensor Technologies, Australia) multisensory capacitance probe (EnviroScan Diviner 2000) was used to measure soil water content within and below the root zone in the soil profile and the data was analysed to calculate ETc. The water budget and water balance methods were used to estimate the water requirement in this study. The highest average ETc was during July (407.65 mm) and the lowest was in the month of February (74.20 mm). Evapotranspiration rates ranged between 2.72 and 14.21 mm/ d in cv. Siwi, between 2.05 and 11.66 mm/d in Nabusaif and between 2.46 and 14.62 mm/ d in Khalas. The average K_c values in the initial stages were 0.92, 0.80 and 0.92 for cultivars, Siwi, Nabusaif and Khals, respectively. The crop water requirement of these varieties under Kuwait's environmental conditions ranged from 23,392 - 27,251 m^3/ha/yr and the net irrigation requirement (NIR) ranged between 23,377 and 27,236 m^3/ ha/yr.

Key words: Evapotranspiration · Water requirements · Net irrigation requirement

INTRODUCTION

Date palm is a fruit tree which adapts well to harsh arid climate and soils of Kuwait. The average daily water use in mature date palm trees of Saudi Arabia was found to be 184.4 l/day [1]. In perennial crops like date palm, it is necessary to know both the total and seasonal water requirements to estimate match plant requirements with the available water supply. The crop water use during developmental stages depends on the daily evapotranspiration (ET) rates which is influenced by the nature of the crop, the developmental stage and the atmospheric conditions (solar radiation, temperature, wind and humidity). This information is essential for sustainable irrigation water management especially in the arid region. Under environmental conditions of Kingdom of Saudi Arabia, Kassem [2] found the evapotranspiration of 'Sukairah' date palm to be approximately 1,644mm or an average of 4.5mm/day by water balance method and 1,775.7 mm or an average of 4.8mm/day by Bowen ratio energy method. The average crop coefficient (K_C) for this variety was 0.6. The overestimation of water requirements results in wastage of precious water resources and impacts adversely at the economic, social and environmental levels. A correct estimation of ETc allows improved water management by changing the volume and frequency of irrigation based on actual crop requirements and soil characteristics. The daily and seasonal gross irrigation requirements for date palm off shoots were estimated to be 51.3 l/ day and 2,191 m^3 /ha year in Saudi Arabia [3].

The present study aims to measure the ET_c of the three most popular date palm varieties using drainage lysimeters, determining the ET_0 using lysimeters and the Penman-Monteith equation and to determine the irrigation needs (IRS) and NIR of young date palms of the three varieties selected.

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MATERIALS AND METHODS

Thirty-three drainage lysimeters (ten for each date palm variety and three additional for grass) measuring 1.0 m in diameter and 1.5 m in height were used in the experiment [4]. The lysimeters were placed on the compacted bottom of a 1.5-m deep hole in the soil and fitted with suitable inlets for irrigation and outlets for collecting drained water. The lysimeters were filled with native soil after placing a 15-cm layer of graded gravel at the bottom to facilitate drainage. An underground passage was provided to allow access to measure the drainage water. These lysimeters were surrounded by plants of the same variety as were planted inside the lysimeter. Plants in lysimeters were irrigated in the same way (i.e., drip irrigation) as those plants in the surrounding areas to maintain a favorable moisture regime in the root zone. To determine the ET_0, three similar-sized lysimeters were planted in uniform stands of *Pasphalum vaginatum* grass. Since the genetic makeup of the plants influence their growth and development and in turn, their water requirements, tissue-cultured plants of cultivars like Khalas, Siwi and Nabusaif were used to avoid any potential discrepancies in the estimation process. Measured quantities of water were applied to the drainage lysimeters. Frequent irrigation was applied to maintain an unlimited soil moisture regime and the grass in the drainage lysimeters was mowed at 45-d intervals to maintain a uniform stand of grass.

The water budget and water balance methods were used to estimate the water requirement in this study. The results from these two methods were compared in order to develop a standardized procedure to forecast water requirements for date palms under Kuwait's environmental conditions. ET of date palms was determined for different seasons and different developmental stages. For practical purposes ET_c is evaluated as a fraction of the ET_0 where $ETc = K_c*ET_0$ and where K_c is the crop coefficient which takes into account differences between a standard crop taken as reference (as grass) and the date palm under study. The moisture content of the soil in the lysimeters was measured using a portable soil moisture probe (Diviner 2000, Sentek Sensor Technologies, Australia). The data were used to calculate the ET_c and ET_0. In addition to the moisture content at various depths of the soil profile inside the lysimeters, the amount of water drained out of each lysimeter was also measured on a daily basis.

Reference Evapotranspiration (ET_0) for each irrigation interval were estimated using the FAO Penman-Monteith method as described in the revised FAO procedures (Irrigation and Drainage Paper No. 56, Allen *et al*. [5]). This was validated with lysimeters method of calculating ET_0 using *Pasphalum viginatum*. Crop Coefficient (K_c) was estimated for each variety and as the ratio of ET_c/ ET_0 where ET_c is crop (actual) ET and ET_0 is reference evapotranspiration determined using the Penman-Monteith equation.

Crop water requirement (ET_c), IR and NIR were determined by two methods, namely, real-time ET_c measurement and daily ET_o by FAO Penman-Monteith method using CROPWAT decision support system version 8.

RESULTS

The evapotranspiration (ET) varied with the time period depending on the atmospheric temperature and other climatic parameters. The reference crop had higher ET than that of cultivated plants, suggesting greater loss of soil moisture from the reference crop (*Pasphalum viginatum*). However, with the advance of summer season, the water needs of plants increased and the irrigation frequency had to be increased as they showed symptoms of water stress. Data in Table 1 showed the lowest (3.22 mm/ d) and the highest (12.73 mm/ d) ET values were observed in February and June, respectively. The calculated ET_0 during winter months (January - March) ranged between 3.22 and 4.64 mm/ d whereas ET_c ranged from 2.72 - 3.1 mm/ d in Siwi, 2.05 - 2.66 mm/ d in Nabusaif and from 2.46 - 3.16 mm/ d in Khalas (Table 2). With increasing temperatures from April, plants looked more stressed requiring more frequent irrigations. During summer months (June to September), the ET_0 ranged between 10.46 and 12.73 mm/ d. The ET_c values during same period ranged between 10.53 and 14.21 mm/ d in Siwi, between 10.58 and 11.66 mm/ d in Nabusaif and between m 11.80 and 14.62 mm/ d in Khalas (Table 2). The highest ET was recorded during June- July in all varieties.

The crop coefficient (K_c) calculated as a ratio between ET_c and ET_0 for each variety ranged between 0.88 and 1.11 in Siwi, between 0.43 and 1.01 in Nabusaif and between 0.68 and 1.15 in Khalas. The average K_c for the year was 0.92, 0.80 and 0.92 for cvs. Siwi, Nabusaif and Khalas, respectively.

Et_c for different months in each of the three cultivars and ET_0 for different months are shown in Table 3. The annual evapotranspiration was 2,725.08 mm for cv. Siwi, 2,339.16 mm for cv. Nabusaif and 2,707.75 for cv. Khalas with an average for all three varieties being 2,491.22 mm.

Table 1: Monthly Evapotranspiration using Penman-Monteith Equation

Months	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m^2/day	ET_0 mm/day
January	8.7	23.4	54	240	6.7	12.5	3.27
February	11.3	23.6	60	232	4.7	12.2	3.22
March	13.1	27.5	49	264	5.3	15.1	4.64
April	22.5	37.8	20	283	6.4	18.5	8.37
May	23.7	46.4	16	216	8.0	21.9	9.07
June	25.9	48.3	11	350	8.6	23.0	12.73
July	29.1	50.6	14	309	12.0	27.8	12.69
August	28.2	50.0	12	335	8.0	21.1	12.51
September	25.4	44.0	16	314	7.5	18.7	10.46
October	15.4	35.2	27	260	7.2	15.8	6.89
November	7.8	32.0	48	220	7.0	13.3	4.60
December	5.7	24.8	42	271	6.9	12.1	4.04

ET: Evapotranspiration

Table 2: Evapotranspiration of Three Cultivars of Date Palm in the Study Area from January-December 2011 Determined using the Soil Moisture Probe

	Average Daily ET_c (mm/d)				Crop Coefficient (K_c)		
Month	Siwi	Nabusaif	Khalas	Average Daily ET_0 (mm/ d)	Siwi	Nabusaif	Khalas
January	3.19	2.05	2.46	3.27	0.98	0.63	0.75
February	2.72	2.50	2.68	3.22	0.84	0.78	0.83
March	3.10	2.66	3.16	4.64	0.67	0.57	0.68
April	5.68	3.60	5.59	8.37	0.68	0.43	0.68
May	8.99	7.16	7.66	9.07	0.99	0.79	0.84
June	14.21	11.66	12.03	12.73	1.11	0.91	0.95
July	13.57	11.26	14.62	12.69	1.06	0.88	1.15
August	12.53	10.91	13.77	12.51	1.00	0.87	1.10
September	10.53	10.58	11.80	10.46	1.00	1.01	1.13
October	6.90	6.70	7.10	6.89	1.00	0.97	1.03
November	4.33	4.58	4.80	4.60	0.94	1.00	1.04
December	3.54	3.02	3.04	4.04	0.88	0.75	0.75
Average	7.44	6.39	7.39	7.71	0.92	0.80	0.92

Table 3: Annual Evapotranspiration of Three Date Palm Varieties and Average Evapotranspiration

	Monthly ET_c (mm)			
Month	Siwi	Nabusaif	Khalas	Average Monthly ET_c (mm)
January	98.89	63.55	76.26	78.74
February	76.16	70.00	75.04	74.20
March	96.10	82.46	97.96	95.38
April	170.40	108.00	167.70	168.60
May	278.69	221.96	237.46	245.83
June	425.30	349.80	360.90	378.90
July	420.67	349.06	453.22	407.65
August	388.43	338.21	426.87	391.53
September	315.90	317.40	354.00	258.60
October	213.96	207.70	220.10	139.81
November	129.90	137.40	144.00	134.40
December	109.40	93.62	94.24	117.80
Total	2,725.08	2339.16	2,707.75	2,491.44

Crop water requirement calculated based on the annual crop ET_c of the three cultivars tested in this study was 27,251, 23,392 and 27,078 m^3/ ha/ yr for cvs. Siwi, Nabusaif and Khalas, respectively. The average water requirement for date palm under Kuwait's environmental conditions was 24,914 m^3/ ha/ yr.

DISCUSSION

Crop water requirement expressed as crop evapotranspiration (ET_c) forms the main component of irrigation water management. The "water balance" approach, which is based on the difference between the amount of water given to the soil (water input) and amount of water lost to the atmosphere (water output) through evaporation from the soil surface and transpiration from crop on a daily basis is one such method [6].

Under the climatic conditions prevailed at the experimental site (Agriculture Research Station, Sulaibiya), the annual evapotranspiration of one-year old date palms and reference crop was 2,491.44 m^3/ ha. According to Oweis [7], water use of date palms ranged from 28,000 m^3/ha/ year in Iraq to 62,500 m^3/ year in California. However, irrigation water requirements of date palms estimated by FAO [8] were slightly lower: 13,000 - 20,000 m^3/ha/ year for Morocco, 27,000 - 36,000 m^3/ha/ year for California, 22,300 m^3/ha/ year for Egypt, 23,600 m^3/ha/ year for Tunisia, 22,000 - 25,000 m^3/ha/ year for India, 15,000 - 20,000 m^3/ha/ year for Iraq, 25,000 - 32,000 m^3/ha/ year for Jordan valley and 25,000 m^3/ha/ year for South Africa. Under the same growing conditions, date palms require 15,000 m^3/ ha/ year with an irrigation efficiency of 90% and zero leaching to 55,000 m^3/ha/ year with 40% irrigation efficiency and 0.1 ration of leaching [9]. The daily water demand for date palms also varies according to the season (from 97 liters per plant in December to 854 liters per plant in June [10], the location of plants within the same plantation and different regions within the same country due to different soil and climatic conditions [8].

Although crops continuously use water, the amount of water used depends on real time evapotranspiration rate, which is influenced by the growth rate, developmental stage, the degree of maturity and the atmospheric conditions at that moment (solar radiation, temperature, wind and humidity). Some crops are able to withstand drought or excess soil moisture conditions better than others. The time of maximum water demand also varies with stage of development [11]. Irrigation water needs are generally low during the initial growth stages, but increases exponentially during the vegetative phases [12] and then again, decrease during flowering and fruiting stages. The annual potential ET_0 of Kuwait was estimated as 2,883 mm and annual crop water requirement (ET_c), irrigation requirement (IR) and net irrigation requirement (NIR) of date palm were estimated at 2,685 mm, 2553 mm and 2,563.9 mm, respectively where a monthly ET_c varied between 74 (January) to 392 mm (June) [10].

CONCLUSION

Evapotranspiration rates ranged between 2.72 and 14.21 mm/d in cv. Siwi, between 2.05 and 11.66 mm/ d in Nabusaif and between 2.46 and 14.62 mm/ d in Khalas. The highest ET was observed during June and July. The average K_c values in the initial stages were 0.92, 0.80 and 0.92 for cvs. Siwi, Nabusaif and Khals, respectively. Based the annual evapotranspiration, the water requirement of these varieties under Kuwait's environmental conditions ranged from 23,392 - 27,251 m^3/ ha/ y. The net irrigation requirement (NIR) of cvs. Siiwi, Nabusaif and Khalas is 27,236, 23,377 and 27,063 m^3/ ha/ yr, respectively.

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