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Determination Actual Evapotranspiration and Crop Coefficients of Date Palm Trees (*Phoenix dactylifera*) in the Jordan Valley

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Abstract: The date palm actual evapotranspiration (Etc) and crop coefficient of Medjool cultivar (*Phoenix dactylifera*) under different water regimes (50, 75. 100 and 125% of Etc) were determined at the Central Jordan Valley during 2011 growing season using Randomized Complete Block Design (RCBD). Twelve years age old date trees with eight meter spacing between trees and rows were used.The experimental plot size contained 12 trees using full automated drip irrigation supplied with fertigation system. Water balance budget method using Neutron Probe technique was used to determine Etc. The required climatic data for estimation of reference crop potential evapotranspiration using Penman-Montieth method were collected from a nearby climatic station. The seasonal amounts of applied irrigation water per date palm tree were 27, 40, 53 and 67 m^3 for the irrigation treatments 50, 75, 100 and 125% Etc respectively, while the precipitation during the growing season was 245 mm. The annual measured date palm tree Etc values were 1327, 1639, 1828 and 1987 mm, for the studied irrigation treatments, respectively, while the estimated potential evapotranspiration was 1920 mm with kc ranged between 0.5 to 1.18 during the growing season. The Medjool crop yield were 33.46, 35.98, 37.8 and 42.49 kg per tree with water productivity of 1.25, 0.90, 0.71 and 0.64 kg m^{-3}, for the 50, 75. 100 and 125% of Etc, respectively, also the date palms yield and growth parameters were significantly affected by irrigation treatments and second degree polynomial relationship between the water applied and crop production was obtained also. The application of 50 and 75% of Etc was significantly increased the soil salinity by 1.5 to 3.7 units at the end of the growing season, while no significant effect when applying 100 and 125% of Etc.

Key words: Date palm · Actual evapotranspiration · Crop coefficient · Water productivity and Neutron Probe

INTRODUCTION

Limited water resources in Jordan are considered as the main challenge facing agricultural development and sustainability. The gap between irrigation supply and demand is increasing from year to year due to the high population growing rate and the people movement from the neighbor countries to Jordan seeking for the stability and peace. Searching for new water resource in Jordan is too difficult and very expensive process, so the shortest way is to maximize the water use efficiency throughout optimizing water use efficiency and the first step on that is determination of the actual crop water requirements.

Jordan Valley is the most important and ancient irrigated agriculture area in Jordan which is characterized by special climate and location for successful cultivation in all seasons. The date palm tree is considered as one of the most important fruit crop in its high nutrition values. The planted area of Date palm trees were increased by more than 13 times during the last 16 years in Jordan Valley (from 75.4 ha in 1994 to a bout 1000 ha in 2010) [7].

Madjuol is the most famous variety and widely distributed in the Valley because of its big size and achieved high profit especially inside and outside markets.

The previous studies showed that date palm trees to produce one kg of fruits needs about 2 m^3 of irrigation water [6] and its water requirement varied according the climate and, crop age and location. The date tree consumes annually from 200 to 250 m^3[11] while the yearly dates crop water requirement in Sodua Arabia ranged from 2700 to 3800 mm using under surface irrigation. The

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seasonal gross irrigation requirements for date palm off shoots were 2191 m^3 $ha^{-1}year^{-1}$, while the farmers added irrigation water nine times as much as the actual gross irrigation requirements [1],. Also in KSA, the date palm evapotranspiration throughout one year approximately 1644 mm while the crop coefficients values ranged from 0.56 to 0.70 [9].

The Dates palm trees are considered one of the most tolerent for water and tempreture deficit but at the end these conditions will afect on the quantity and quality of crop yield [4]. Also it has been recoded some differences in dates water requirement according the climate and locations differences, it was ranged between 1500 to 3500mm in Algeria from 2700 to 3600mm in the United State and a bout 2230 mm in Egypt and from 2500 to 3200mm in Iraq while it s value ranged from 1300 to 2000 mm and in the South Africa reached 2500mm. In Tunisia the monthly water consumption ranged between 133.9 mm to 1648mm [10]. Abdu Salam and AL Maszroeei (2007) estimated the yearly potential and actual evapotranspiration in Kuwait to be 2883 and 2685 mm, respectively and they found a large variation in monthly water consumption ranged between 74 mm in January and 392 mm in June. Also it has been estimated date palm crop evapotranspiration theoretically using Penman-Monteith equation in six deferent locations to be from 1500 to 5000 mm according to location and irrigation water quality differences [3].

AI-Amoud *et al.* [2] conducted a field experiment to investigate the response of date palm trees, of Seleg cultivar, to different water regimes (50, 100 and 150% of pan evaporation rate), using three irrigation methods: basin, bubbler and trickle irrigation systems. The study was conducted during four successive years (1991 through 1994). The results of this study demonstrated the general trend of yield increase as irrigation quantity increases. The maximum yield was produced from palm trees irrigated with the trickle irrigation system followed by the basin method. Results on experiments of date palm water consumption in Riyadh area, have indicated that the average amounts that have been delivered to date palms per year were; 108, 216 and 324 m3 per tree for corresponding water treatments of 50%, 100% and 150% of evaporation rate, respectively.

Date palms were found to be much less tolerant to salinity than expected based on previous literature. Trees irrigated with low salinity (EC = 1.8 dS m^{-1}) water were almost twice the size (based on ET and growth rates) than trees irrigated with EC = 4 dS m^{-1} water after 5 years. Fruit production of the larger trees was 35–50% greater than for the smaller, salt affected, trees. Long term irrigation with very high EC of irrigation water (8 and 12 dS m^{-1}) was found to be commercially impractical as growth and yield were severely reduced [13]

Also there was no available information concerning palm trees evapotranspiration and crop coefficients in Jordan so this study was conducted to achieve the following objectives:

- Determine the actual evapotranspiration for mature palm trees by depletion method using neutron scattering technique.
- Determine crop coefficients for palm trees using Penmen or Penmen-Monteith equation as potential evapotranspiration(from metrological stations)
- Draw Production function curve and select the optimum irrigation level (deficit irrigation index)
- Study the effect of deferent irrigation levels on the salt accumulation in the soil.

MATERIAL AND METHODS

This study was conducted at the Deir-Alla Regional Center for Agricultural Research and Extension of date palm tress at The Central Jordan Valley, The Hashemite Kingdom of Jordan during 2011 growing season. The geographical location of the farm is 32° 00' N latitude, 35° 18' E longitude and 224 m altitude below the sea level. The experiment was implemented on Medjool date palm trees (11 years old) using Randomized Completely Block Design (RCBD) with four replications. Four irrigation levels were applied 50%, 75%, 100% and 125% of actual evapotranspiration (Etc). Each treatment contains 12 trees and all analysis were don for the central two and the other 10 trees were considered as border. The actual evapotranspiration (Etc) were measured by soil moisture depletion method using neutron probe instrument. The purpose of this research is to determine the weekly water requirements throughout the productive cycle of a date palm tree Medjool variety, by using soil moisture depletion using water balance (SWB) method by Neutron Probe technique which considered as the most accurate soil moisture measurement device [12]. The Jordan Valley has semi arid climate. The hourly climatic averages for the growing 2011 season were recorded from Deir-Alla Metrological Station, These values were used to determine the daily reference evapotranspiration (ETo) by Penman–Monteith's model. The soil of the field site is classified as Clay soil without groundwater table to a depth of until 10 m. The irrigation water was obtained from King Talal Dam though the Authority of the Jordan

Valley. The irrigation water has a pH of 8.4 and total soluble salts of 1450 ppm. Sodium adsorption ratio (SAR) value was 2.7. Field measurements were taken during the productive cycle of eleven years old date palm tree "Medjool" variety from 1 January 2011to 31 December 2011. The date palm trees had an average height of trunk 2.2 m; average diameter of trunk 27 cm; average long of palm leaves is 272 cm and average number of leaves are 44 per a tree and average tree shaded area was 47%. The date palm productive cycle had five stages, started with a pollination stage (from 15 March to 15 April); Hababouk stage (from 2 April to 19 May); Kimri stage (from 20 May to 30 July); Khalal stage (from 1 August to 28 August) and Tamer stage (from 29 August to 30 September). The date palm trees spaced of 8.0 m between rows by 8.0 m between trees. Drip irrigation system was used to irrigate date palm trees, each date palm tree was irrigated by a lateral line around a tree in a circle shape and the distance between the lateral line and the date palm trunk wag 1.47 m, 37 inline pressure compensated emitters were used to irrigate the date palm tree. The discharge rate was 4 L h^{-1} for each emitter at inlet pressure one bar. Before beginning the experimental study, a soil profile (1.5 m depth, 1.0 m width and 2.0 m length) was open in the experimental plot for extracting undisturbed soil samples, with three repetitions, at the same soil depths. These soil samples were used for determining the soil texture (soil mechanical analysis), field capacity, wilting point and bulk density according to Anter et. *al*. [5]. The physical and hydraulic properties of the soil are presented in Table (1). All these measures were made in the National Center for Agriculture research and Extension libratory at Deir Alla. It has been recommended that the fertilizers application rate were (N= 63, P=15.5 and K=65 kg ha^{-1}) [14].

For calculation of crop evapotranspiration we used the following soil water balance (SWB) method (equation 1),

$$(I + P) - (ET_a + D + R) = \pm \Delta S \quad (1)$$

Where:

I = Irrigation water (mm)
P = Precipitation (mm)
ET = Actual evapotranspiration (mm)
D = Drainage (mm) determined as the depth of water drained below 150 cm of soil depth
ΔS = Soil moisture deference between two respective irrigation events. root zone depth within time interval Ä*t* (mm)
R = Surface runoff (considered zero in the drip irrigation system)

Reference Evapotranspiration): Et_o): FAO Penman Monteith Model [8], was used in estimation of Eto using the required climatic data from a nearby metrological station at Dair-Alla Regional Center during 2011 year (Equation 2).

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (2)$$

Where;

Et_o = Potential evapotranspiration for the Reference crop (mm day^{-1})
R_n = Net solar radiation (MJ $m^{-2} day^{-1}$)
G = Soil heat flux (MJ $m^{-2} day^{-1}$)
T = Mean air temperature at 2 m height (C °)
U_2 = Wind speed at 2 m height (m s^{-1})
Es-ea = Vapor pressure deficit (KPas)
Δ = lope of vapor pressure curve (KPas m^{-1})
γ = Moisture constant (KPas m^{-1})
900 = conversion factor

Table 1: Selected physical and chemical properties of soil at Deir-Alla Research Station in the Jordan Valley 2011

Soil depth Cm	SG (1)	FC% (2)	PWP % (3)	Textural class
0 - 25	1.27	33.00	21.1	Clay
26-50	1.31	32.50	22.2	Silt Clay
51-75	1.32	33.00	21.9	Silt Clay
46-100	1.37	34.50	22.9	Silt Clay Loam
101-150	1.40	36.80	22.95	Silt Clay Loam

(1) Specific gravity.(SG)

(2) Field capacity, % by volume.

(3) Wilting point, % by volume.

Soil water moisture was monitoring using Neutron probe sensor after predicting the required calibrations throughout two PVC access tubes installed in the central tree shaded area perpendicular to each other with 44mm in diameter and 2.5 m depth and the soil moisture readings were taken before each irrigation and calculated the average of the two access tubes at 10, 30, 50, 70, 90, 110, 130, 150, 170, 190, 210 and 230 cm soil depths.

The date palm crop coefficients were calculated on weekly and monthly basis using the following equation:

$$Kc = \frac{Etc}{Eto} \quad (3)$$

Where;

Kc = crop coefficient

Etc = Date palm actual evapotranspiration for application of 100%of Etc(mm day^{-1})

Eto = Potential evapotranspiration for the reference crop (mm day^{-1})

RESULTS AND DISCUSSIONS

Climatic Conditions in the Experimental Site: The observed daily average values of the climatic variables for experimental site are shown in Table (2). The data revealed that the mean maximum monthly temperature was 40.6°C during the June to September, while the lowest main monthly temperature was 13.4°C for December. The highest maximum relative humidity was 72.8 % during the February; while the lowest minimum relative humidity was 18.6 % during July. The total rainfall was about 245 mm and the highest wind speed was 2.5 ms^{-1} in March. The maximum mean daily value of net radiation was 29.6 MJ in June.

Yield Parameters: Before starting the experiment the date palm tree average shaded area were measured to be 47% and there were no significant differences between the studied trees (Table 3) which means a good uniformity was achieved before starting the study that reduced the error in determination of water requirements for deferent irrigation treatments.

The results indicated a significant increase in date's fruit weight by 47 and 27% when applying 125% of Etc comparing with the treatment 50% during Kalal and Tamer stage, respectively. About 40% increased in leaves growth rate by adding 125% of Etc comparing with 50% of Etc water application and made the significant differences in actual evapotranspiration values according irrigation treatments, meanwhile there were no significant differences between total soluble percentage values as affected by irrigation amounts meanwhile there were a significant effect of deferent irrigation levels on the yield and reflected that on plant water use (Table 3).

Amount of the Applied Water: A 47% covered area (30.08 m2) wetting surface area was used for determining the irrigation water amount to be applied to the soil. The total amount of the applied was 26.7, 40.1, 53.4 and 66.8 m^3 tree^{-1} for 50, 75, 100 and 125%of Etc, respectively (Table 3).

Evapotranspiration of the Date Palm Tree by Soil Water Balance Method: The terms of the soil water balance method equation, used to determine the crop evapotranspiration of the date palm tree on weekly and monthly basis are presented in Figure 2 and Table (4), respectively. The date palm tree evapotranspiration obtained by the soil water balance method—ETc (SWB),

Table 2: Average monthly maximum (Tmax) and minimum (Tmin) temperature, wind speed (Wind), solar radiation (Rs), maximum (RHmax)and minimum(RHmin) relative humidity

Month	Tmax C°	Tmin C°	Wind Ms^{-1}	Rs MJ	RHmax %	RHmin %	Rain mm
January	21.2	13.9	1.0	10.9	66.5	38.6	41.9
February	21.5	13.8	0.9	12.5	72.8	39.5	23.6
March	24.7	14.3	2.5	18.8	69.9	29.5	35.1
April	28.5	16.8	2.1	21.8	68.0	27.2	31.0
May	33.0	20.1	2.0	25.9	65.7	22.7	3.0
June	36.7	23.3	2.0	29.6	66.9	22.5	0.0
July	40.6	26.0	2.2	28.6	64.9	18.6	0.0
August	39.2	26.8	2.0	25.7	64.6	24.0	0.0
September	37.1	25.3	0.8	21.5	67.3	24.5	17.3
October	32.7	22.5	0.4	18.3	56.3	23.9	1.0
November	23.8	15.6	0.5	13.3	61.9	33.9	80.8
December	21.8	13.6	0.9	11.7	48.5	25.0	10.9
Mean	30.1	19.3	1.4	19.9	64.4	27.5	

Table 3: Palm Tree yield parameters as affected by different levels of water application

	Irrigation treatments as a percentage of crop evapotranspiration (%)			
Yield parameters	50	75	100	125
Actual evapotranspiration (mm)	1327.3 d	1639.2 c	1828.4 b	1987.4 a
Annual water applied (m^3 $tree^{-1}$)	26.7	40.1	53.4	66.8
Average fruit weight (gm)	11.95 b	12.85 b	13.50 ab	15.18 a
Fruits pulp percentage (%)	11.64 b	12.72 b	15.70 a	17.06 a
Total Soluble Solids percentage (%)	90.32 b	90.68 b	91.47 b	92.85 a
Average leaf growth in five months (cm)	50.46 a	51.95 a	48.35 a	50.40 a
Date palm yield (kg per tree)	33.46 b	35.98 b	37.80 ab	42.49 a
Tree shaded area percentage (%)	46.69 a	48.88 a	46.97 a	47.51 a

Table 4: Monthly actual evapotranspiration (mm) of date palm under deferent irrigation treatments and the reference crop potential evapotranspiration (kc) at Jordan Valley during 2011 growing season.

	Irrigation treatments (% of Etc))					
Month	50	75	100	125	Eto (mm)	Kc
January	1.9	2.0	2.0	2.3	2.7	0.76
February	2.2	2.2	2.3	2.5	3.0	0.77
March	3.9	4.1	4.4	5	4.5	0.98
April	4.0	4.4	5.2	5.7	5.2	0.99
May	4.3	5.6	6.7	7.2	6.3	1.07
June	5.1	6.6	8.8	9.1	7.4	1.18
July	5.5	7.2	9.9	10.5	8.8	1.12
August	4.9	6.8	7.6	8.1	7.4	1.02
September	4.1	5.7	5.3	5.8	6.0	0.88
October	3.4	4.4	3.6	4.1	4.6	0.78
November	2.5	2.8	2.3	2.7	3.3	0.71
December	1.6	2.0	1.9	2.0	3.8	0.50
Sum	1327.3	1639.2	1828.4	1987.4	1919.9	
Mean	3.6	4.5	5.0	5.4	5.3	0.90

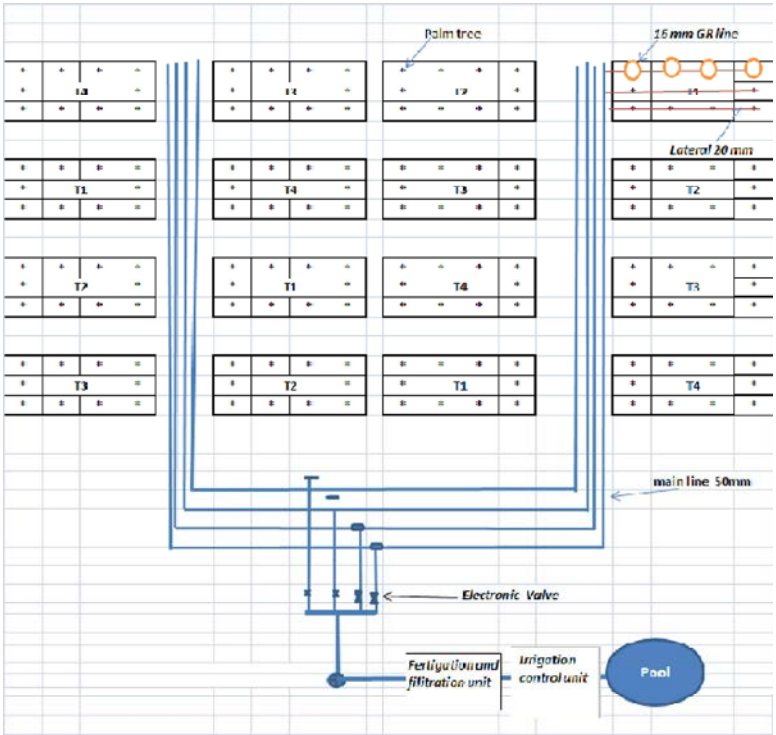

Fig. 1: Date palm experimental layout at Dair-Alla Research Station during2011 growing season.

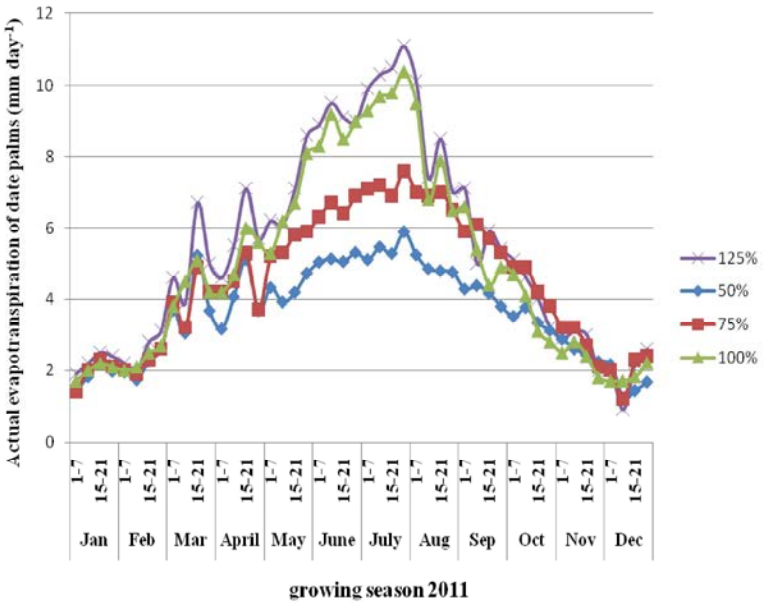

Fig. 2: Average weekly date palm actual evapotranspiration (Etc) for the studied irrigation treatments and the estimated potential evapotranspiration (Eto) at the Jordan Valley during 2011 growing season.

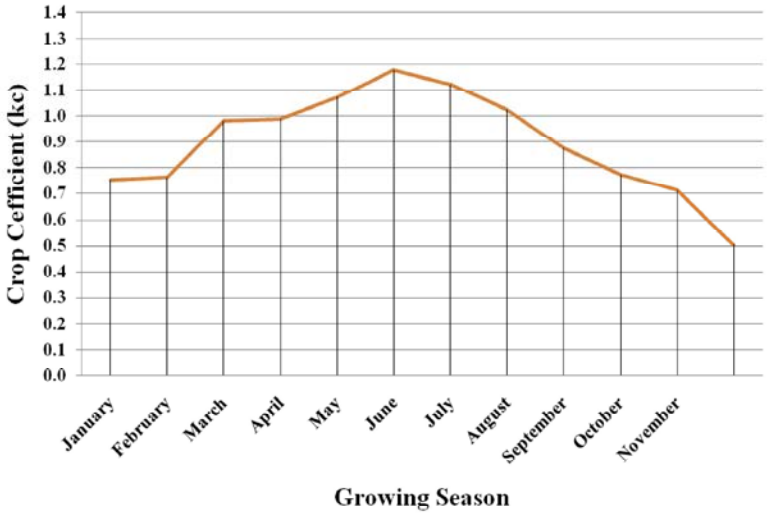

Fig. 3: Date Palm crop coefficient (Medjool) at Jordan Valley during 2011 growing season.

increased from 2.5 mm per day in February month before pollination stage to 9.9 mm per day in July month at the kalal stage then it decreased to 5.3 mm per day in September month at the end of tamer stage. After the date palm tree harvest, the Etc of the date palm tree was declined to reach the minimum values of Etc 1.9 mm per day at the periods of December and January months.

The maximum values of the Etc(100%ETo) of the date palm tree were 8.8 and 9.9 mm/day in July and June months, respectively, where the date palm tree at the fruits formation stage (Kimri and kalal stages) and the climatic conditions of temperature air; wind speed, net radiation and sun shine were high and the relative humidity was low, Table (2). The minimum value of Etc was 1.9 mm day^{-1} in December and January months, where the date palm tree was pruned. Also, the maximum and minimum of Etc occurred in the periods of high and low evaporative rates, respectively. The estimated Potentiah evapotranspiration (Eto) throughout the year 2011 was approximately 1920 mm, with a daily average of Et0= 5.3 mm day^{-1} Table (4). Figure (3). represented the Etc values for the deferent treatments were almost the same during the first three months. When the crop started the hababouk stage the deference's in water consumption

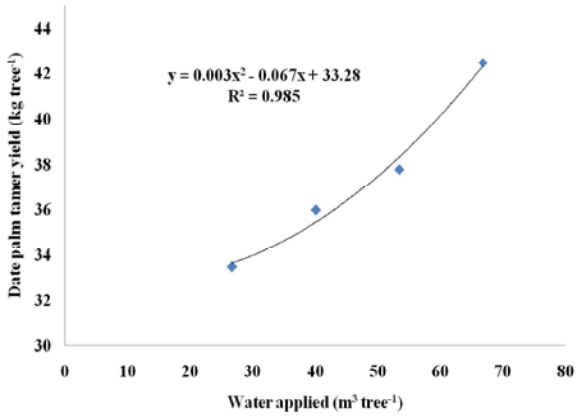

Fig. 4: Date palm tree yield and water application relationship for Medjool variety at the Jordan Valley 2011.

was cleared among the irrigation treatments and it reached the highest values during kalal stage (August) and started decreased after October. The total yearly Eta for date palm tree in the Jordan Valley for Medjool variety are 1327, 1639, 1828 and 1987 mm for the application of irrigation water by 50, 75, 100 and 125% of Etc, respectively.

Crop Coefficient of the Date Palm Tree: Values of the date palm tree crop coefficient, obtained by the SWB method are presented in figure (3). This figure shows that the date palm tree crop coefficient is greater than 1 throughout its productive cycle. The crop coefficient of the date palm tree increased from 0.76 in February month at pollination stage to than 1.18in June month at the kalal stage then it decreased to 0.78 in October month at the end of tamer stage and continue decreasing during the date palm tree harvest, the crop coefficient of the date palm tree was decreased to its lowest value 0.5 in December due to low temperature and pruning process. This result was agreed with results in Kingdom of Saudi Arabia that the date palm kc is not constant during the growing season [9].

Date Palm Irrigation Water Productivity: A polynomial relation was predicted between date palm tree yield (kg) and the applied water per tree (m^3) (Fig. 4) as follows:

$$Y = 0.003X^2 - 0.067\ X + 33.28, \quad R^2 = 0.985 \qquad (4)$$

Where;
Y = Tamer yield (kg $tree^{-1}$);
X = water applied ($m^3\ tree^{-1}$)

This relation means that the dates yield was increased by increasing the amounts of water application that also due to the irrigation water quality (Ec=2.3 dS m^{-1} and SAR 3.7).

The average productivity of one cubic meter was 1.25, 0.90, 0.71 and 0.64 for the application treatments 50, 75, 100 and 125%, respectively. We can't advice the farmer to not use the treatments 50 and 75 % of Eto under irrigation with this quality of water so using the 100% will be more useful.

Salt Accumulation and Sodium Adsorption Ratio in the Soil Profile: The chemical analysis for the irrigation water are shown in Table 5 and the average EC values during the growing season was 2.3 dS m^{-1} and it has contained a valuable nutrients such as N, Ca, Mg, P and K which taken in the account during fertigation process. Soil chemical analysis before starting the study and after the yield harvesting were investigated to one meter soil profile are represented in Table 5 and 6, respectively. Soil salinity and sodium Absorption Ratio (SAR) are represented in Figure 4 and 5 respectively.

Table 5. Irrigation water chemical properties at the Cental Jordan Valley during 2011 growing season

Month	PH	ECdS m^{-1}	TSSppm	NO3 ppm	NH4 ppm	N ppm	PO4 ppm	K ppm	Na ppm	Mg ppm	Ca ppm
Jan	8.7	2.05	1312	12.47	0.79	13.26	1.28	21.70	189.0	65.35	120.0
Feb	8.7	2.04	1289	11.92	0.80	12.72	1.41	22.20	198.2	67.20	118.9
March	8.7	2.05	1312	12.47	0.79	13.26	1.28	21.70	189.0	65.35	120.0
April	8.5	2.00	1280	11.02	0.34	11.36	2.83	21.40	193.0	67.92	102.6
May	8.5	2.20	1398	10.05	0.45	10.50	2.20	22.12	212.5	87.89	120.4
June	8.6	2.30	1472	10.19	0.79	10.98	1.28	20.00	182.0	107.3	108.0
July	8.7	2.40	1536	8.76	0.71	9.47	2.83	21.60	225.9	78.23	137.3
Aug	8.7	2.54	1589	9.00	0.60	8.40	1.85	23.21	258.2	99.21	132.2
Sept	8.7	2.64	1690	9.26	0.09	9.35	1.76	25.90	271.6	89.19	125.1
Oct	8.6	2.60	1664	9.16	0.57	9.73	1.19	45.24	343.6	59.99	138.0
Nov	8.6	2.57	1645	10.68	0.57	11.25	1.73	26.00	278.5	74.34	129.0
Dec	8.6	2.27	1453	11.14	0.17	11.31	2.30	24.90	223.6	62.85	136.6

Table 6: Soil chemical properties for deferent location and depths before starting the study on January 2011.

Irrigation level	Soil Depth cm	SAR	EC dS m^{-1}	OM %	K ppm	Ca ppm	Mg ppm
50%	25	3.0	1.8	0.06	721.5	240.5	60.8
	50	3.5	3.6	0.07	741.0	260.5	328.1
	75	6.1	4.2	0.06	663.0	220.4	243.1
	100	5.8	5.9	0.08	702.0	300.6	303.8
75%	25	2.7	1.9	0.09	663.0	200.4	36.5
	50	3.8	4.0	0.08	2008.5	240.5	158.0
	75	1.2	2.8	0.08	599.0	601.2	510.4
	100	3.2	1.8	0.10	507.0	160.3	194.4
100%	25	5.0	4.1	0.09	741.0	220.4	401.0
	50	4.0	4.2	0.06	643.5	481.0	437.5
	75	5.9	4.1	0.06	702.0	641.3	328.1
	100	6.3	5.1	0.06	936.0	481.0	534.7
125%	25	4.4	3.5	0.10	1209.0	1102.2	911.4
	50	2.7	6.8	0.08	936.0	1082.2	583.3
	75	3.5	5.6	0.10	643.5	360.7	364.6
	100	5.3	3.3	0.08	448.5	380.8	48.6

Table 7: Soil chemical properties for deferent location and depths after date palm harvesting on November 2011.

Irrigation level	Soil Depth cm	SAR	EC dS m^{-1}	OM %	K ppm	Ca ppm	Mg ppm
50%	25	6.1	5.5	0.08	870.3	320.6	218.7
	50	6.9	6.1	0.07	758.8	380.8	243.1
	75	7.5	8.1	0.08	777.4	561.1	328.1
	100	7.5	8.3	0.08	777.4	561.1	340.3
75%	25	5.2	3.4	0.09	628.6	160.3	133.7
	50	5.0	5.7	0.06	637.9	120.2	72.9
	75	4.9	3.3	0.08	684.4	160.3	109.4
	100	5.7	3.7	0.06	647.2	140.3	145.8
100%	25	6.8	5.3	0.07	554.3	521.0	303.8
	50	5.7	3.4	0.06	507.8	440.9	267.4
	75	3.9	4.2	0.05	479.9	300.6	182.3
	100	6.0	4.3	0.04	610.0	481.0	230.9
125%	25	5.1	4.6	0.04	554.3	280.6	194.4
	50	5.5	5.1	0.06	545.0	320.6	267.4
	75	3.4	2.9	0.04	582.1	180.4	145.8
	100	4.5	3.9	0.08	554.3	254.5	185.9

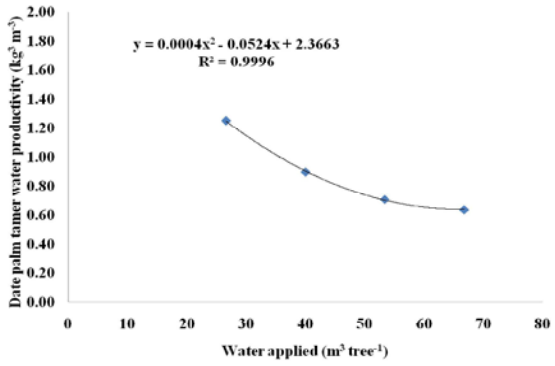

Fig. 5: Water productivity of date palm for medjool variety at Jordan Valley during 2011 growing season.

The soil salinity for irrigation with 50% of Etc increased by 3.7 unites at the end of the growing while it increased 2 units when applying 75%Etc and the SAR value increased by a bout 4 units when applying 50% of Etc and it increased 2 units when applying 75% of Etc. Meanwhile there were no significant increase in soil salinity or SAR when applying 100% and 125% of Etc. This result was agreed with Tripler *et al*. 2011 founding that date palms were found to be much less tolerant to salinity than expected and trees irrigated with low salinity (EC = 1.8 dS m^{-1}) water were almost twice the size (based on ET and growth rates) than trees irrigated with EC = 4 dS m^{-1} water after 5 years.

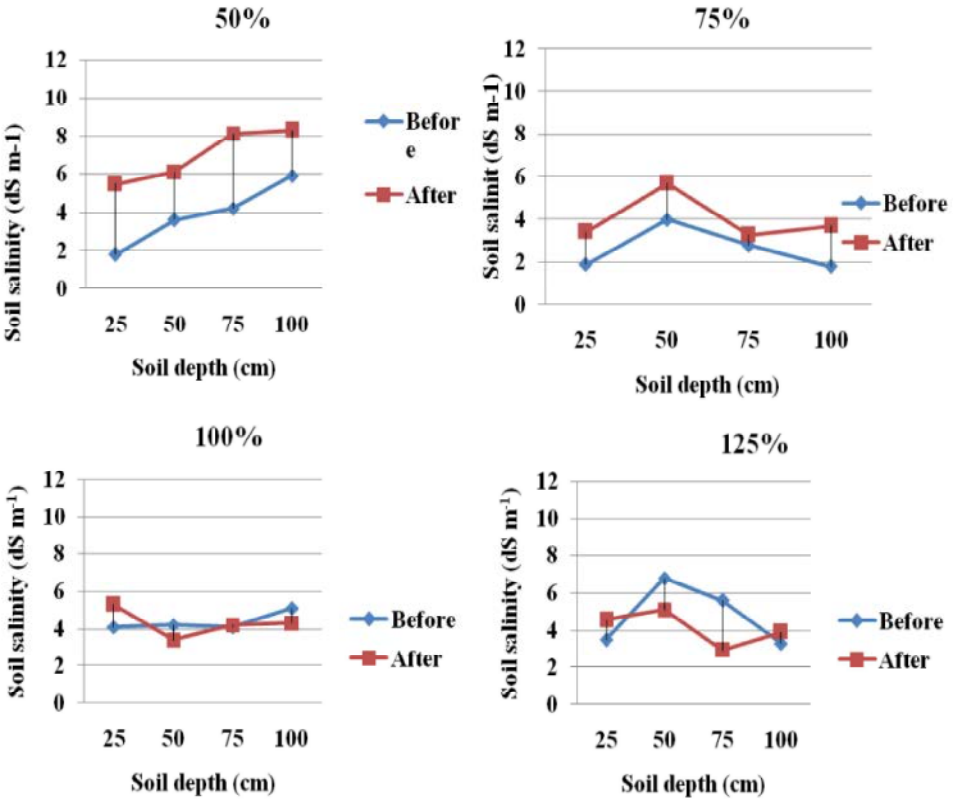

Fig. 6: Effect of deferent amount of water application on soil salinity at the end of the growing season grown with date palms at the Jordan Valley during 2011.

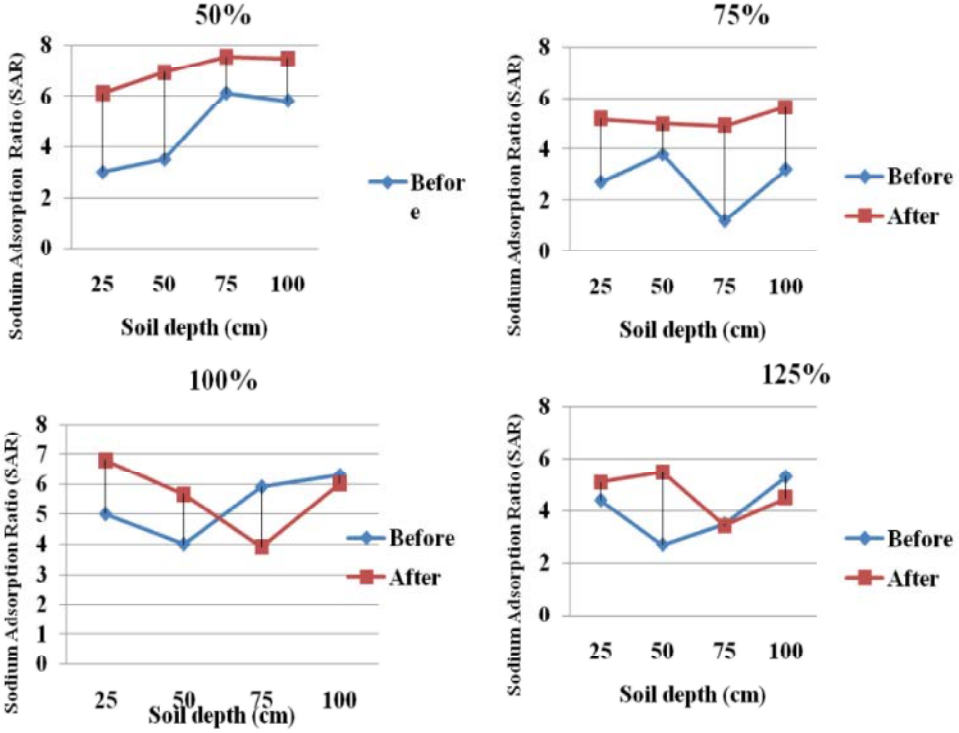

Fig. 7: Effect of deferent amount of water application on soil Sodium Adsorption Ratio (SAR) at the end of the growing season grown with date palms at the Jordan Valley during 2011

CONCLUSIONS

The objective of this research was to determine actual evapotranspiration and crop coefficient values throughout the productive cycle of a date palm tree Medjool variety by using soil water balance (SWB) methods. The results showed that:

- The date palm tree Etc increased from 2.30 mm per day in February month at pollination stage to 9.9 mm per day in July month at the maturity stage then it decreased to 5.3 mm/day in September month at the end of harvest stage. The date palm evapotranspiration throughout one year approximately 1828 mm, with a daily average of ETc= 5.0 mm per day.
- The estimated potential evapotranspiration (Eto) using Penman Monteith method was obtained throughout one year approximately 1920 mm, with a daily average of ETc= 5.3 mm per day.
- The date palm tree crop coefficient is not constant throughout its productive cycle and it was range from 0.5 to 1.18 according to plant growth stages.
- The one year irrigation by using 75 and 50% of actual water requirement increased the soil salinity and SAR by 2 to 4 unites.

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