WATER USE EFFICIENCY FOR JATROPHA IN SANDY SOIL

F. I. Zabady [1], A. A. ELMeseery[2], A. A. Nassar[3], and H. G. Ghanem[4]

ABSTRACT

This study was conducted at Wadi El-Natron area, season (2008-2009), to evaluate the influence of three irrigation systems (Bubbler, Micro-sprinkler and Trickle) on Jatropha production. Also, this work includes different water management techniques, (quantities 60%, 80% and 100% from ET_o and irrigation interval of 2 and 4 days). The objective of the present work is to implement some of these intervals and water deficits in computing actual evapotranspiration of Jatropha under desert conditions, to maximize the seeds oil content production of Jatropha under different irrigation systems to save water .The results are as follows:

- *Highest seeds yield production (302.40 kg/fed), was obtained under bubbler irrigation system at 100% applied irrigation water and 2 days intervals, comparing with micro-sprinkler and trickle irrigation systems (238.48 kg/fed) and (204.80kg/fed), respectively.*
- *Maximum crude Jatropha oil content "CJO" (%) (29.33%) was obtained under trickle irrigation system at 60% applied irrigation water and 4 days intervals, comparing with micro-sprinkler and bubbler systems (24.2%) and (23.21%), respectively.*
- *lowest actual evapotranspiration "ETa" for (initial, development, mid-season, and late-season) growth stages of value were (50.50, 326.37, 671.79 and 142.34) respectively and 1191mm for all-season, were obtained under trickle irrigation system at 60% applied irrigation water with 2 days intervals .*
- *Water use efficiency under bubbler irrigation system at 80% applied water quantity and 2 day intervals (0.18 kg/m^3) was highest than different treatments.*

[1] Lect .Ag. Eng. Dept., Fac. of Ag., Azhar Univ., Cairo, Egypt.
[2] Assoc. Prof., Ag. Eng. Ag. Eng. Dept., Fac. of Ag. Azhar Univ., Cairo, Egypt.
[3] Assoc. Prof. Water Manag and Irri Systems–Nati .Water. Res . C ,Cairo, Egypt.
[4] Post grad. Stud. Agric., Dept., Fac. Ag. Azhar Univ., Cairo, Egypt.

INTRODUCTION

Jatropha curcas Linn has been the focus of research as a substitute to the scare reserves of fossil fuel due to several reasons. A part from being a non-edible oil crop, the crop exhibits growth versatility which makes it easy to be grown under a wide range of soils and climatic types. These characters open an opportunity to many countries in tropical and semi-arid regions to become biofuel producers. Beside the growth characters, their yield variability has been reported in many publications . This variability has been reported to be due to different accessions of *J. curcas* from diverse agro climatic regions **(Kaushik 2007) .**Also, the oil content is higher, which is about 63.16% compared to linseed, soybean, and palm kernel oil, which contain only 33.33, 18.35 and 44.6%, respectively **(Gunstone, 2004).** The crude *Jatropha* oil (CJO)content has been related to harvesting time .Jatropha needs around 90 days to mature from the day after fruit bloom**. (Jupikely et al. 2010)**. The 90 days as an indication of harvest time by previous researches was due to a claim that black dry fruit results in high CJO. In contrast to the recommended harvesting time, **Wanita and Hartono (2006)** reported that high CJO in *Jatropha* fruits was from fully yellow color fruits or when bunch age is 45 days. The CJO was reported to be around 36.83 and 63.06% in seeds and kernels respectively .It is important to note that not all oils in the kernels can be extracted during extraction .Oil extraction was reported to range from 70 – 80 % **(Achten et al. 2008) .** The yield of extracted oil was 28.69, 58.39, 30.17 and 22.15 kg ha^{-1} at 125%, 100%, 75% and 50% of potential evapotranspiration, respectively at micro-sprinkler system. The lowest values of total lipid (oil) (25% and 24.5% of *Jatropha* seeds) were recorded with *Jatropha* trees that were irrigated by 125% and 50% of ETp, respectively. On the other hand, the treatment that was irrigated by 100% of ETp (control) recorded the highest value of total oil in the seeds (29.93%). There are no significant difference among the values of oil characteristics due to different water stress ratios. The highest characteristics of Jatropha seed oil were recorded with 100% of ETp. In addition; water stress had no significant effect on the fatty acid composition of Jatropha seed oil**(Kheira and Atta, 2009)**. The crop coefficient of both olive and fig trees grown in El-Sheikh Zewid, North

Sinai (الشيخ زويد،شمال سيناء),and Egypt increased with the increase of irrigation water amounts, adding organic manure and trees age. Meanwhile Kc values tend to decrease by using black plastic mulch **(Seidhom, 2001).**

MATERIALS AND METHODS

2.1. Experimental treatments:

The main experiments were carried out during the season of (2008- 2009) at Wadi EL Natrown(وادى النطرون)On-Farm Irrigation Department Research Station, Water Management and Irrigation Systems Research Institute, El-Behera governorate Egypt(محافظة البحيره), to study Jatropha irrigation scheduling. The Wadi El-Natrun Research Station lies at 30° 25' 0 N latitude, 30° 13' 0 E longitude, while the altitude is 36 m above the sea level **.**The field study was carried out in split – split plot design with two replicates. The distance between the trees was 5 x 5 (m). The experiment was started in march (2008-2009) after 3 years from Jatropha planted at 168 tree/fed . Mean height of tree at starting was 155 (cm).

Mean diameter of stok at distance 40 (cm) from soil was 8 (cm) and the mean area of tree shade at 12 pm was 1.76 (m^2). The sub-main plots were irrigated by three applied water quantities (Q)(60%, 80% and 100%) obtained from the product of the reference evapotranspiration (ETo) calculated by using Penman-Montieth equation multiplied by crop coefficient for every stage .The sub sub-main plots were two intervals as 2 and 4 days as water distribution under three irrigation systems, (Bubbler, Micro-sprinkler and Trickle).

The reference evapotranspiration (ETo) was calculated by using "CropWat 4 windows" (version 3.4), **Smith (1991)** Software Program, according to the monthly mean of 30 years. Moreover, Table (4) illustrates the growth periods (days) of the Jatropha crop, i.e., establishment or initial stage, vegetative or development stage, flowering or mid-season and yield formation or late-season.

Table (4): Period length (days), crop coefficient (Kc_{FAO}) and reference evapotranspiration (ETo) of Jatropha growth stages and total season.

Stages	Initial	Develop	Mid	Late	Total
Period length (day)	25	40	65	50	180
Kc_{FAO}	0.35	1.15	1.15	0.35	--------
ETo (mm)	217	384.8	778.6	579.3	1959.7

2.2. Soil characteristics:

Some physical properties of soil were measured in the Laboratory of Water Requirements and Meteorology unit associated with the Physical and Chemical Department in Agricultural Research Center, Ministry of Agriculturel, El-Doky, Cairo, Egypt as represented in Table (1).

Table (1):some physical characteristics of the soil under study.

Soil depth (cm)	Particle size distribution, %				Textural class	$CaCO_3$ %	P.D. g/cm^3	B.D. g/cm^3	H.C. cm/h	F.C. %	W.P. %	A.W. %
	C. sand	M. sand	F. sand	V.F. sand								
0-30	2.10	87.52	8.13	2.25	S.	1.61	2.58	1.58	8.27	9.14	2.38	6.76
30-60	5.59	79.84	9.91	4.66	S.	1.84	2.63	1.55	4.80	9.67	2.42	7.25

Coarse (C.), medium (M.), fine (F.) and very fine (V.F.), sand. S. = sand, P.D. = particle density (g/cm^3), B.D. = Bulk density (g/cm^3), H.C. =Hydraulic Conductivity (cm/h), F.C. =Field capacity (0.1 atm.)%, W.P. =Permanent Wilting Percentage (15atm) % and A.W. =Available soil water %.

The amounts of irrigation water were calculated using the following equation:

$$I.W. = \frac{ETo * KC * Ti * A * Li}{\eta} \quad m^3 \quad (1)$$

Where:

I.W : amount of irrigation water, m^3 per irr.

ETo : potential evapotranspiration, mm / day.
Kc : crop coefficient from FAO.
Ti : irrigation frequency in days (2and4 days).
A : the mean area of tree shade, m^2.
η : irrigation systems efficiency (%)
Li : leaching requirements (10%)

2.3. Actual evapotranspiration "ETa" (mm/day) determination technique:

To determine water consumption of Jatropha, soil samples were collected from each treatment at 0 – 30 cm and 30 – 60 cm soil depths periodically before and after each irrigation. The crop water consumptive use was calculated by the following equation:

$$ETa = \frac{(M_2\ \% - M_1\ \%)\ x\ d_b\ x\ D}{100} \quad mm \quad (3)$$

Where:

ETa : actual evapotranspiration, mm.
M_2 : moisture content after irrigation %.
M_1 : moisture content before irrigation %.
d_b : specific density of soil .
D : mean depth of root (600mm).

2.4. Water use efficiency"WUE" (kg/m^3) determination:

Water use efficiency was calculated by dividing the crop yield by the amount of seasonal water consumptive use.

$$WUE = Y/CU \quad kg/m^3 \quad (4)$$

Where:

Y : dry yield or marketable dry matter, kg.
CU: seasonal water consumptive use (m^3).

2.5. Water application efficiency "WAE"(%):

$$WAE = W_S / IW \quad (5)$$

Where:

WAE: water application efficiency.
Ws : water storage in effective root zone.
IW : amount of irrigation water, m^3 per irr.

2.6. Statistical analysis:

Statistica software program &SPSS software was used according to SPSS Inc. according that **Snedecor G. W. and Cochran W.G. (1982)**.

RESULTS AND DISCUSSION

3.1. Growth parameters:

3.1.1. Height of plant "H" (%):

Data in Figure (1) shows that the height of plant "H" (m) increases with the increase of applied water quantities and decreasing the intervals for bubbler, micro-sprinkler and trickle irrigation systems. The maximum mean value of height increases percentage was 33.5 % at 100% applied water quantity and 2 days intervals for bubbler irrigation system. Meanwhile the minimum mean value of height increase percentage was 13.5 % at 60% applied water quantity and 4 days intervals for trickle irrigation system.

The data revealed that the values of height percentage were no significant affected by changing intervals between 2 and 4 days and difference between applied water quantities 100% and 80% for all conditions under study. Meanwhile there was significantly for applied water quantity 60%.

3.1.2. Diameter of plant "D" (%)

Data in Figure (1) shows that the Diameter of plant increases with the increase of applied water quantities and decreased intervals for bubbler, micro-sprinkler and trickle irrigation systems. The maximum mean value of diameter increase percentage was 43.8 (%) at 100% applied water quantity and 2 days intervals for bubbler irrigation system. Meanwhile the minimum mean value increase percentage was 16.7 (%) at 60% applied water quantity and 4 days intervals for trickle irrigation system.

3.1.3. The mean area of tree shade"A" (%)

Data in Figure (1) shows that the mean area of tree shade increases with the increase of applied water quantities and decreasing the intervals for bubbler, micro-sprinkler and trickle irrigation systems. The maximum mean value of area increase percentage was 32.8 (%) at 100% applied water quantity and 2 day intervals for bubbler irrigation system. Meanwhile the minimum mean value increase percentage was 15 (%) at 60% applied water quantity and 4 days intervals for trickle irrigation system.

3.2. Crude oil content percentage "CJO" (%):

Data in Figure (2) shows that the crude oil content percentage "CJO" (%) increases with the decrease of applied water quantities and increased intervals for bubbler, micro-sprinkler and trickle irrigation systems. The maximum mean value of "CJO" was 29.33% at 60% applied water quantity and 4 days intervals for trickle irrigation system. Meanwhile the minimum mean value was 16.21% at 100% applied water quantity and 2 days intervals for bubbler irrigation system.

3.3. Jatropha seeds yield" Sy" (kg/fed):

Data in Figure (2) shows that the seeds yield "Sy" kg/fed increases with the increase of applied water quantities and decreased intervals for bubbler, micro-sprinkler and trickle irrigation systems. The maximum mean value of "Sy" was 302.40 kg/fed at 100% applied irrigation water and 2 days intervals for bubbler irrigation system. Meanwhile the minimum mean value was 102.44 kg/fed at 60% applied irrigation water and 4 days intervals for trickle irrigation system.

The data revealed that the values of "Sy" kg/fed were no significant affected by changing intervals between 2 and 4 days and difference between applied water quantities 100% and 80% for all conditions under study. Meanwhile there was significantly for applied water quantity 60%. So, it is recommended to use applied water quantaities, (80%) to save 20% water.

3.4. Water use efficiency "WUE" kg/m^3:

Data in Figure (2) shows that the maximum value of"WUE" was 0.18 kg/m^3, at 80% applied irrigation water and 2 days intervals for bubbler irrigation system. Meanwhile the minimum value was 0.04 kg/m^3, at 60% applied irrigation water and 4 days intervals for trickle irrigation system.

3.5. Actual evapotranspiration "ETa" (mm) for all growth stages:

Data in Figure (3) shows that the maximum mean values of actual evapotranspiration "Eta" for (initial, development, mid-season ,and late-season) growth stages were 87.41, 469.28, 960.29, and 243.09 mm respectively, and whole season 1760.07 mm at 100% applied irrigation water and 4 days intervals for bubbler irrigation system. Meanwhile the minimum mean values were 50.50, 326.37, 671.79, 142.34 and 1191mm respectively, at 60% applied irrigation water and 2 days intervals for trickle irrigation.

3.6. Water application efficiency "WAE"(%):

Data in Figure (4) shows that the maximum of water application efficiency "WAE" was 94.27% at 60% applied irrigation water and 2 day intervals for trickle irrigation system. Meanwhile the minimum was 68.2% at 100% applied irrigation water and 4 days intervals for bubbler irrigation system.

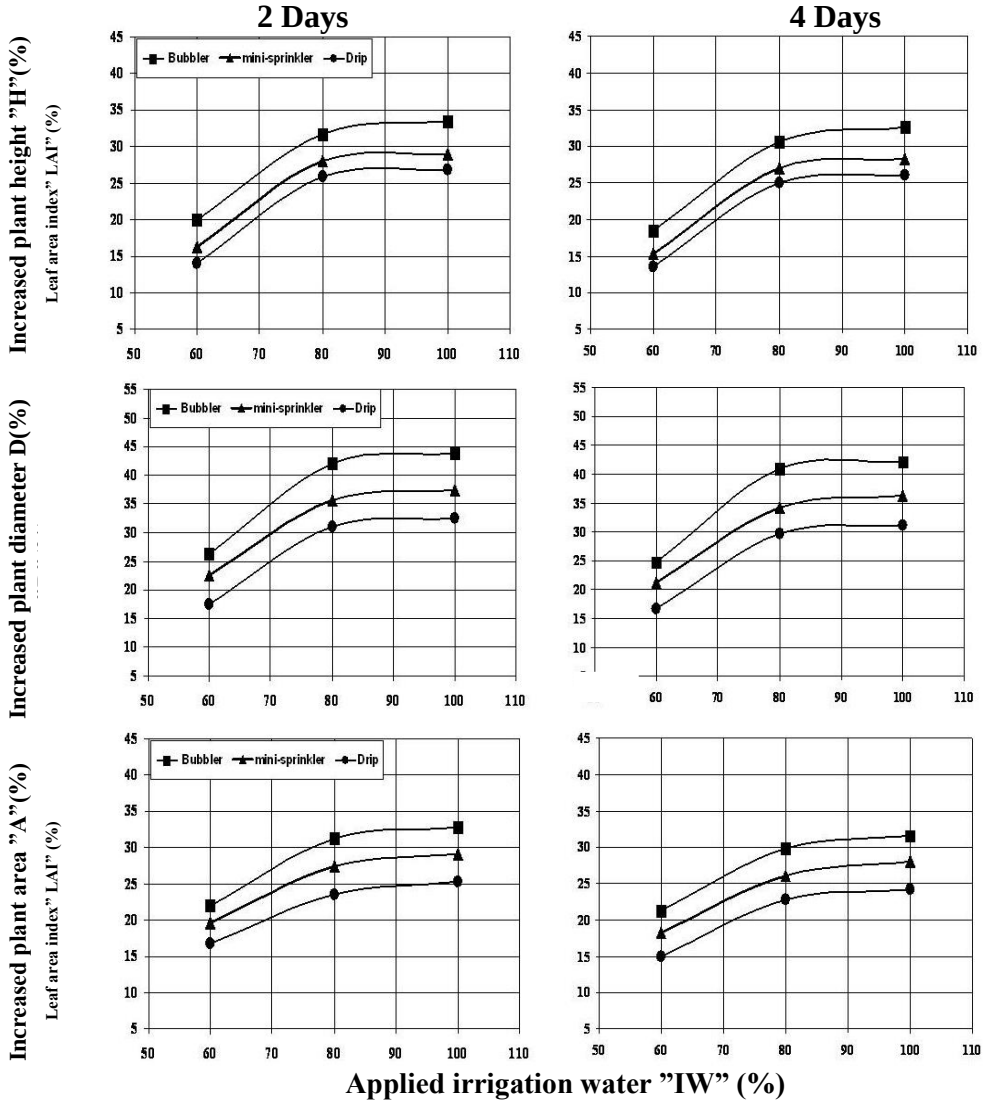

Fig.(1): Increased Plant height "H"(%), plant diameter "D"(%) and plant area "A"(%) at applied irrigation water "IW" (%) and different intervals "Int." (Days) for bubbler, micro- sprinkler and trickle irrigation systems on *Jatropha.*

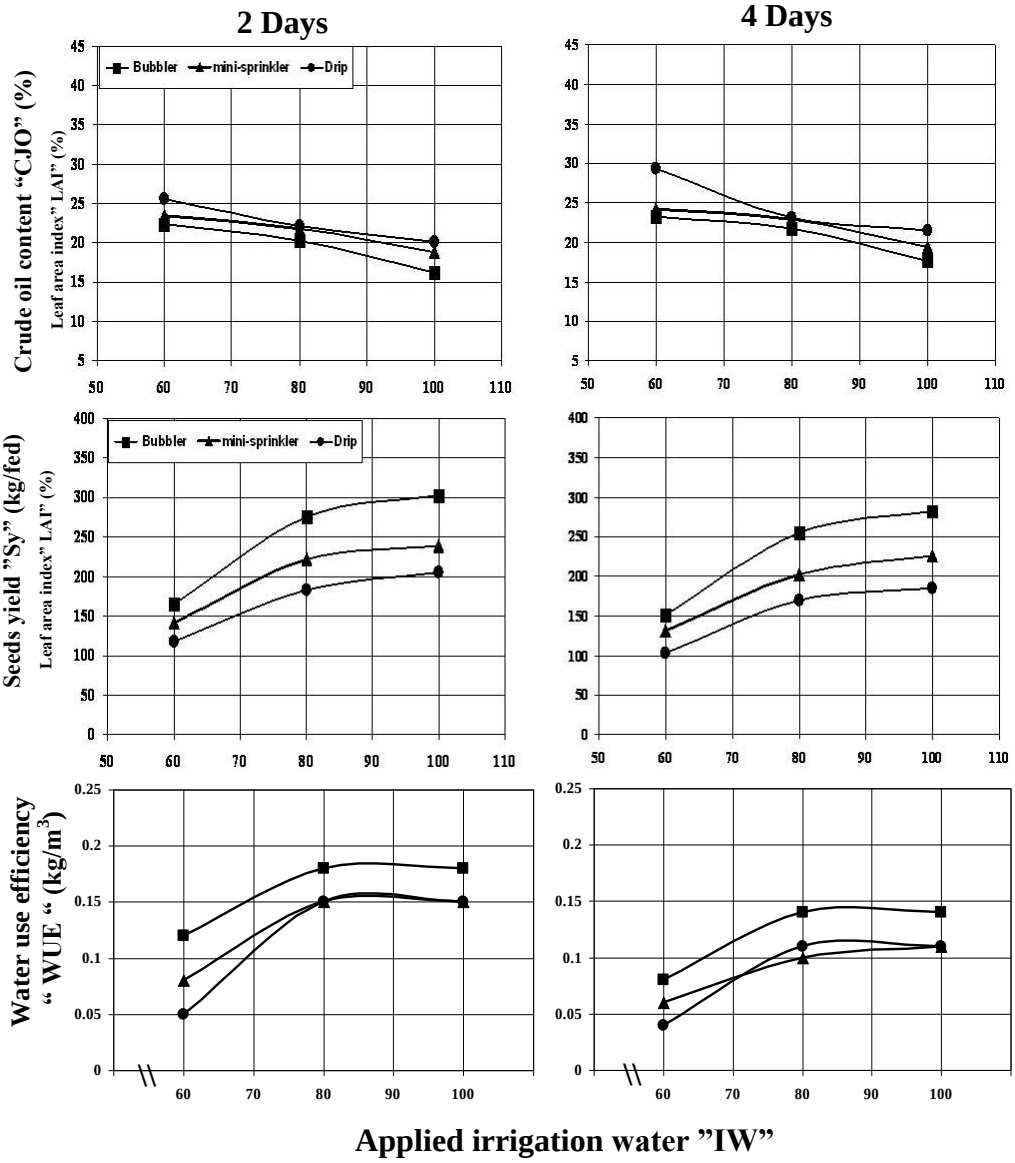

Fig.(2): crude oil content "CJO" (%), Seeds yield "Sy" (kg/fed) and water use efficency (kg/m^3) at applied irrigation water "IW" (%) and different intervals "Int." (Days) for bubbler, micro- sprinkler and trickle irrigation systems on *Jatropha.*

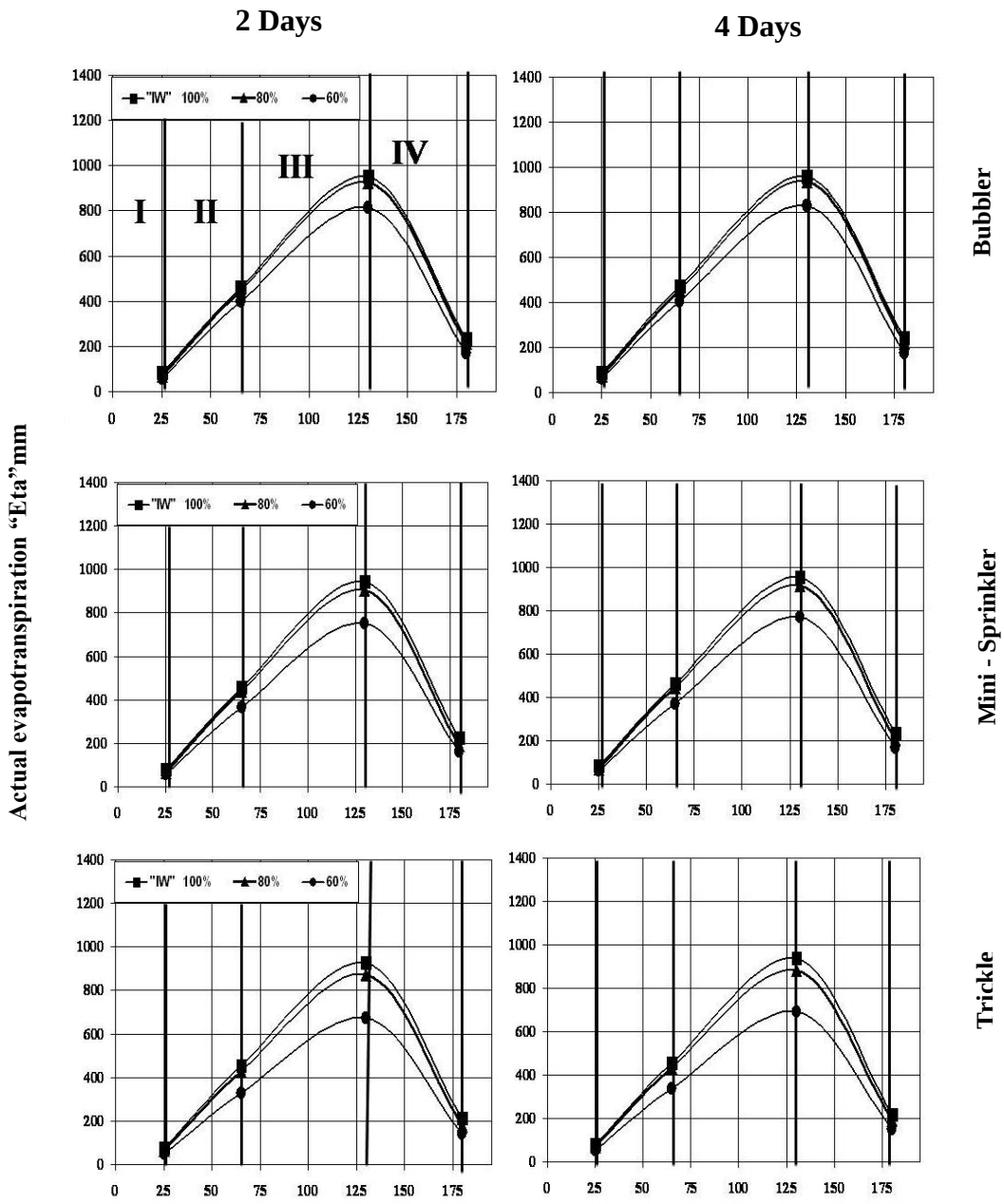

Fig.(3): Actual evapotranspiration "Eta" (mm) for all growth stages at different applied irrigation water "IW" (%) and different intervals "Int." (Days) for bubbler, micro-sprinkler and trickle irrigation systems on *Jatropha*.

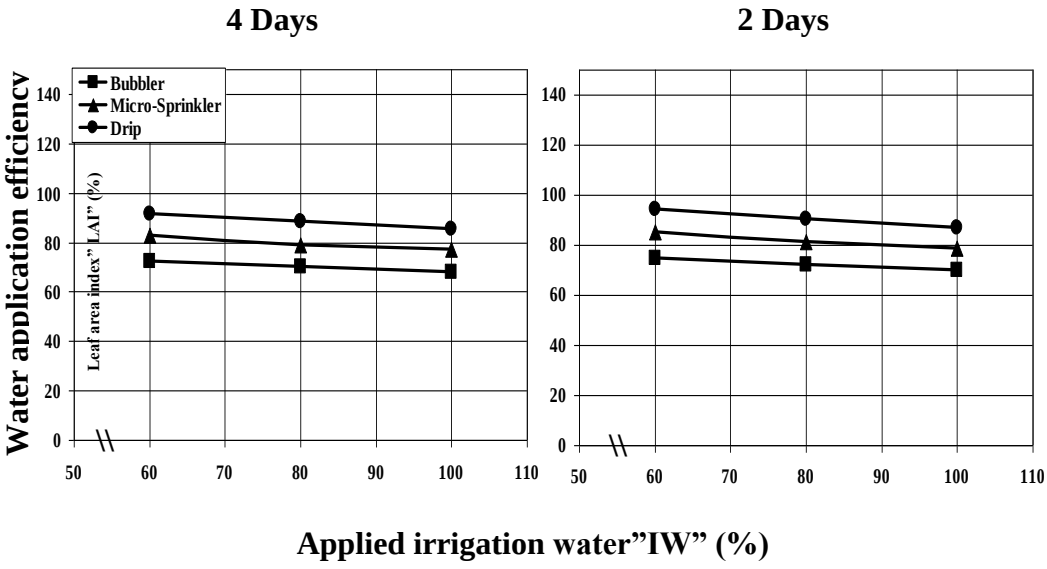

Fig.(4): Water application efficiency "WAE"(%) at applied irrigation water "IW" (%) and different intervals "Int." (Days) for bubbler, micro- sprinkler and trickle irrigation systems on *Jatropha.*

CONCLUSIONS

Results could be summarized as follows:

1- The values of "Sy" **"** (kg/fed) , "H" (%) and "CJO" (%)were no significant affected by changing intervals between 2 and 4 days and difference between applied water quantities 100% and 80% for all conditions under study. Meanwhile there were significantly for applied water quantity 60%.

2- The maximum mean value(%) of "Sy" and "H" were (302.40 kg/fed and 33.5 %) respectively, at 100% applied irrigation water and 2 day intervals for bubbler irrigation. Meanwhile the minimum mean values were (102.44 kg/fed and 13.5 %) at 60% applied irrigation water and 4 day intervals for trickle irrigation system.

3- The maximum mean seasonal value of "ETa" was 1760.07 mm/season, at 100% applied irrigation water and 4 day intervals for bubbler irrigation system. Meanwhile the minimum mean value was 1191 mm/season at 60% applied irrigation water and 2 day intervals for trickle irrigation system.

4- The maximum mean value of "WUE" was 0.18 kg/m^3, at 80% applied irrigation water and 2 days intervals for bubbler irrigation system. Meanwhile the minimum mean value was 0.04 kg/m^3, at 60% applied irrigation water and 4 day intervals for trickle irrigation.

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الملخص العربى

"كفاءة الأستهلاك المائى للجتروفا فى الأراضى الرملية "

فتحي إبراهيم زبادي[١] *علاء الدين على محمد المسيري[٢] *عاطف عبد الغفار نصار[٣]

- **حامد جودة عبد المنعم غانم [٤]**

أجريت هذه الدراسة خلال الموسم ٢٠٠٨ – ٢٠٠٩ بمنطقة وادى النطرون والتى تهدف الى تطبيق ثلاثة أنظمة رى وهى (النافورى والرش والتنقيط) وتحديد أيها أنسب فى انتاج بذور الجتروفا فى الأراضى الصحراوية بأقل أستهلاك مائى، وتحديد أنسب كمية مياة مضافة يجب تطبيقها وتحديد أنسب فترة بين الريات وحساب كفاءة الأستهلاك المائى للجتروفا تحت نظم الرى الثلاثة تحت ظروف منطقة وادى النطرون .

وكانت أهم النتائج المتحصل عليها هى :

١- نبات الجتروفا سجل أعلى أنتاجية فى البذور (٣٠٢,٤٠ كج/ فدان) وذلك عند اضافة كمية المياه (١٠٠%) من البخر نتح المرجعى عند الفترة بين الريات يومين وذلك تحت نظام الرى النافورى، بينما سجل أقل قيمة (١٠٢,٤٤ كج/ فدان) وذلك عند اضافة كمية المياه (٦٠%) عند الفترة بين الريات أربعة أيام وذلك تحت نظام الرى بالتنقيط .

٢- سجلت بذور الجتروفا أعلى نسبة فى محتوى الزيت (٢٩,٣٠%) عند اضافة كمية المياه (٦٠%) عند الفترة بين الريات أربعة أيام وذلك تحت نظام الرى بالتنقيط،بينما سجل أقل قيمة (١٦,٢١%) وذلك عند اضافة كمية المياه (١٠٠%) عند الفترة بين الريات يومين وذلك تحت نظام الرى النافورى.

٣- سجل نبات الجتروفا أعلى استهلاك مائي (١٧٦٠,٠٧ مم /موسم) وذلك عند اضافة كمية المياه (١٠٠%) عند الفترة بين الريات أربعة أيام،وذلك تحت نظام الرى النافورى بينما سجل أقل قيمة فى الاستهلاك المائي (١١٩١ مم /موسم) وذلك عند إضافة كمية المياه (٦٠%) عند الفترة بين الريات يومين وذلك تحت نظام الري بالتنقيط .

٤- سجل نبات الجتروفا أعلى كفاءة فى أستهلاك المياه (٠,١٨ كج/ م^{٣}) وذلك عند اضافة كمية المياه (٨٠%) عند الفترة بين الريات يومين وذلك تحت نظام الرى النافورى،بينما سجل أقل كفاءة للأستهلاك المائى (٠,٠٤ كج/ م^{٣}) وذلك عند اضافة كمية المياه (٦٠%) عند الفترة بين الريات أربعة أيام وذلك تحت نظام الرى بالتنقيط.

٥- سجل نبات الجتروفا أعلى قيمة فى كفاءة إضافة المياه ٩٤,٢٧% وذلك عند إضافة كمية المياه (٦٠%) عند الفترة بين الريات يومان وذلك تحت نظام الري بالتنقيط،بينما سجل أقل قيمه في كفاءة إضافة المياه ٦٨,٢% وذلك عند إضافة كمية المياه (١٠٠%) عند الفترة بين الريات أربعة أيام وذلك تحت نظام الري النافورى .

[١] **مدرس بقسم الهندسة الزراعية - كلية الزراعة – جامعة الأزهر بالقاهرة.**
[٢] **أستاذ مساعد بقسم الهندسة الزراعية- كلية الزراعة – جامعة الأزهر بالقاهرة.**
[٣] **أستاذ مساعد بمعهد بحوث وإدارة المياه – القاهرة.**
[٤] **طالب دراسات عليا بقسم الهندسة الزراعية- كلية الزراعة – جامعة الأزهر بالقاهرة.**