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Energy, economic analysis and efficiencies of micro drip irrigation I- Energy Analysis

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Abstract: *Research study was carried out for two successive seasons 2012 and 2013 on seven years old (Florda prince) peach trees (Purnus perseca L. Batsch) budded on Nemagard rootstock. The experiment was conducted at the experimental farm, modern reclamation lands, situated Bader City, South Al-Tahrir, Al-Beharia Governate, Egypt.*

Peach trees were planted at 5 x 4 m in sandy soil, and were irrigated using four techniques of drip irrigation systems: Gr surfacr drip (SD) 4 l/h., Gr subsurface drip (SSD), surface micro drip (SMD) 0.5 l/h, and subsurface micro drip(SSMD) under three amount of applied water (60, 80, 100% of applied water will be called T_1, T_2 and T_3). Fourty two experimental trees were selected of normal growth with uniform of vigor. Statistical design was split with three replicets. And results show that,

The best irrigation water save is 20% for T_2 under all of SMD and SSMD irrigation system, on the other hand, T_1 under SMD irrigation system in all of first and second year is acceptance by irrigation water saving ratio 40%, the high gradation for CWUE under various water amounts, T_1 water treatment is the higher value then T_2 and T_3 under various drip irrigation systems

The mean value of EEIS higher percentage in SSMD and SMD irrigation systems than its counterpart in SSD and SD irrigation system, beside at under all of SSMD irrigation systems is increasing with water amount increasing, energy applied efficiency of for SMD and SSMD irrigation systems is higher more than SD and SSD irrigation systems, the higher value of A.I.E.I. is 0.19 (MJ/M^3-yr.) under SD and SSD for T_3 water treatment, while the smallest the higher value of A.I.E.I. is 0.13 (MJ/M^3-yr.) Under SMD and SSMD irrigation systems for T_3 water treatment. A.I.E.I is increasing with applied water increasing, whenever the applied water increase the energy production is reduced. The average energy production under SMD and SSMD irrigation systems is higher than SD and SSD irrigation systems by 18.8%,cost of unit production unit (LE/kg) for SSMD and SMD irrigation systems are lower than SSD and SD irrigation systems by (32-38,3%) at first season and (28,7-32%) at second season approximately.

Energy applied efficiency for SMD and SSMD irrigation systems is higher more than SD and SSD irrigation systems, as a result of variation of energy requirements and productivity of SMD and SSMD irrigation systems, SSMD and SMD irrigation system were more economical compared with SD and SSD irrigation systems.And saving on peach yield quantity and quality characterizes.

Keywords:*micro-irrigation, drip irrigation water-save, peach trees,water use efficiency***,** *peach quality yield, Energy.*

I. Introduction

Water resource management is the activity of planning, developing, distributing and managing the optimum use of water resources. It is a sub-set of water cycle management. Agriculture is the largest user of the world's freshwater resources, consuming 70 percent. As the world's population rises and consumes more food, industries and urban development's expand, and the emerging bio-fuel crops trade also demands a share of freshwater resources, water scarcity is becoming an important issue.

The main aims of research are energy, economic analysis and efficiencies of micro drip irrigation to determine the economic impact which related to dripper flow rate, and behavior of various irrigation efficiencies under various flow rates of drip irrigation systems.

Energy is a fundamental ingredient in the process of economic development, as it provides essential services that maintain economic activity and the quality of human life. Modern agriculture has become very energy-intensive. Energy in agriculture is important in termsof crop production and agroprocessing for value adding. The aims of this study were to determine energy consumption and energyindexes in peach production, to investigate the efficiency of energy consumption and to make an economic analysis of peach orchards, accordign to **Zarini and Asadollah (2014).**

(**Mead, 2002**) definedmicro irrigation is usually 10 times less than common emitters.(**Lubars, 2008**) mention Advantages of this system are **1)** Optimum growth conditions due to the ability to maintain,**2)** optimum balance of air, water and nutrients in the soil, 3) Better utilization of available space, Plant density can be Increased, **4)** Quicker turnaround of plant materials reducing growth cycles,**5)** Higher yields, **6)** Minimize leaching of nutrients that occurs with excess water Flow, **7)** The micro rate system is much cheaper than the common micro-irrigation systems, smaller P.V.C. tubes size reduced horse power requirements,**8)** No runoff on heavy soils, **9)** No water loss through the root zone on very sandy soils, **10)** Water and fertilizer saving up to (40-50) %, **11)** Better quality, and**12)** Water could be applied efficiently on shallow soils in hilly areas.

Abdouet al, (2010) mention by comparing traditional trickle flow 8 L/h and micro rate system 0.4 L/h for the same water quantity 2.4 Liter, wetting pattern front for sand and clay soils at traditional trickle flow were faster than wetting pattern front at microirrigation system, which led to a significant loss in the amount of water by deep percolation in a short time, in traditional trickle flow the vertical wetting pattern fronts in sandy soil increase more than vertical in clay with 646.15%, but the horizontal wetting pattern front in clay soil increase more than horizontal in sand with 8.8%.

II. Matrials And Methods

Research study was carried out for two successive seasons 2012 and 2013 on seven years old Florda prince peach trees (Purnus perseca L. Batsch) budded on Nemagard rootstock. The experiment was conducted at the experimental farm, modern reclamation lands, situated Bader City, south Al-Tahrir, Al-Beharia Governate, Egypt.

Peach trees (seven years) were planted at 5 x 4 m in sandy soil, this investigation aimed to study the effect of irrigation using four techniques of drip irrigation systems: surface drip (SD) 4 l/h., Gr subsurface drip (SSD), surface micro drip (SMD) 0.5l/h, and subsurface micro drip (SSMD) under three amounts of applied water (60, 80, 100% of calculated applied water called T_1, T_2 and T_3) on yield, fruit quality and some leaf parameters peach trees.

Fertilization program:

For peach trees, amounts of fertilizers are applied according to the recommendations of Field Crop Institute, ARC, Egypt, Ministry of Agricultural and Land Reclamation for Peaches trees .

Irrigation system:

The irrigation system consisted of the following components:

a- Control head:

Control head consisted of centrifugal pump 5 /5 inches(20 m lift and 80 m3/h discharge), driven by diesel engine (50 Hp), Control head consisted of centrifugal pump 5/5 inches(20 m lift and 80 m3/h discharge), driven by diesel engine (50 Hp), pressure gauges, control valves, inflow gauges, water source in the form of an aquifer, main line then lateral lines and dripper lines. For traditional drip irrigation, Gr dripper (4 l/h/m discharge, two dripper at one meter) was used, every trees row has two hoses and the one tree was 64 l/h.tree, where micro drip irrigation was one hose for every tree row, total discharge, and one dripper 8l/h.tree with 4 cross four distributor to result 2l/h., a (Fig., 1), in drip irrigation systems, the total dripper discharge for one tree was 64l/h (16 dripper X 4l/h) while for micro drip irrigation systems, the tree discharge was 8l/h (4 distributor X 2l/h).

Irrigation requirements:

Irrigation water requirements for peach trees were calculated according to the local weather station data at Al-Beharia Governorate, belonged to the Central Laboratory for Agricultural Climate **(C.L.A.C.),** Ministry of Agriculture and Land Reclamation.

Irrigation process was done by calculated crop consumptive use (mm/day) according to **Doorenbos and Pruitt(1977).**

Water requirements for Peach trees were calculated according to the following equation as recommended by **Keller and Karmeli (1975).** Table (1) and table (2).

$$IR = \left[\frac{K_c \times Et_o \times A \times C_E}{10^7 \times Ea} \right] \cancel{+ LR} \text{ ----------------- (1)}$$

Where:

IR	=	Irrigation water requirements, m^3/ha/day.
E t_o	=	Potential evapo-transpiration, mm day^{-1}
Kc	=	Crop factor of peach,
A	=	Area irrigated, (m^2)
Ea	=	Application efficiency, %,where 90% drip irrigation.

LR = Leaching requirements.
C_F = Covering factor, for peach trees 45%.

Crop factor of peach was used to calculate Et_{crop} values, according to **FAO,(1984).**

Table (1): Calculated consumptive use (mm/day) of peach trees.

Growth stage	month	ET_o mm/day	K_c	Et_c mm/day	I_t (L/tree/ day)	I_d (m^3/ha/ day)
Initial	January	2.4	0.48	1.152	11.5	5.78
	February	3.2	0.48	1.536	15.4	7.72
	march	4.2	0.48	2.016	20.2	10.11
Mid-season	April	5.6	0.79	4.424	44.2	22.20
	May	6.6	0.79	5.214	52.1	26.17
	June	7.3	0.79	5.767	57.7	28.94
	July	7.2	0.79	5.688	56.9	28.54
Season end	Augusts	6.7	0.75	5.025	50.3	25.21
	September	5.6	0.75	4.2	42.0	21.08
Total (I_y)			5781.44 (m^3/ha/season).			

Where:

I_t = Irrigation requirements for tree per day (L/ha/day),
I_d = Irrigation requirements for ha per day (m^3/ha/day),
I_y = Irrigation requirements for ha per season (m^3/ha/season).

Table (2): Calculated water amounts versus irrigation systems for peach trees.

Characters	Irrigation requirements per season for hectare (m^3/ha/season)
60% ETC = (T_1)	3468.86
80% ETC = (T_2)	4625.15
100% ETC = (T_3)	5781.44

Fig. (1). Micro drip irrigation dripper, 2 l/h but every dripper have a cross four distributor to result 0.5 l/h.

Measurements and calculations:

Energy analysis:

Total energy inputs into irrigation:

The total energy inputs into irrigation were determined by an annual basis and by both area and volume of applied water.

Basis, The total seasonal energy is the sum of the seasonal fixed installation energy and the seasonal operation energy, **Down et al. (1986).**

- The seasonal fixed installation energy is the energy required to install the irrigation system for a useful life of at least the length of some evaluation period divided by the number years of the period. In this study, the evaluation period was twenty years.

- Energy associated with transporting of different components to the site was not considered in this study, because of unreliable data records.

The total irrigation energy calculations procedure:

The total seasonal irrigation energy is the sum of the seasonal installation; operating (pumping plus maintenance) and human labor energies were evaluated as follows:

Installation energy:

The installation energy includes:

(a) The annual fixed energy to manufacture a limited number of products used in irrigation system was calculated by method of **Batty and Keller (1980):**

$$\mathrm{AFE} = \frac{(\mathrm{ERM} + \mathrm{ERC})(\mathrm{NTR})}{(\mathrm{ESL})}$$

Where:

AFE	=	Annual fixed energy, (MJ/kg-yr.),
ERM	=	Energy input to manufacture products from raw materials, (MJ/kg.),
ERC	=	Energy input to manufacture products from recycled materials (MJ/kg.),
NTR	=	Number of times product is replaced over the expected life of the system, and
ESL	=	Expected system life, (years).

-The manufacturing energy for certain products used in irrigation system by **Batty and Keller, (l980),**

(b) Energy required manufacturing equipment or machinery.

(ME) which used in excavation and land forming was computed bythe following relationship, **(Batty et al. (1975):**

$$\mathrm{ME} = \left[\mathrm{kW} \times 14.88\ \frac{\mathrm{MJ}}{\mathrm{kW}} + \mathrm{Equip.Wt.} \times 71.2\ \frac{\mathrm{MJ}}{\mathrm{ton}}\right] \times \frac{\mathrm{hoursonjob}}{\mathrm{expectedlife, h}}$$

Where:

ME	=	Manufacture energy.
kW	=	Engine power, kW.

(c) Energy associated with fuel consumption was computed directly on the basis on 4l.06 MJ / liter, **Batty et al. (1975).**

(d) Energy associated with the repairs and maintenance of the machinery was estimated as 5 percent of machinery energy inputs,**Larson and Fangmeier (I987).**

(e) Human labor energy associated was estimated as follows. **Kassem (1986):**

$$\mathrm{EHL} = \frac{\mathrm{CHL}}{\mathrm{Fc}} \times \mathrm{NL}$$

Where:

EHL	=	human labor energy. MJ per fed,
CHL	=	Energy input coeffienet represent the human labor energy,2.3, MJ/man-h,
NL	=	Number of laborers required for any operation, and
Fc	=	Field capacity, ha per h.

Operation energy:

Energy inputs in operation tor irrigation system including maintenance and pumping energies:

(a) Annual maintenance energy for irrigation system was roughly estimated as 3 percent of annual installation energy. **Batty et al. (l975).**

(b) The pumping energy was calculated directly by the following:

relationship, **lsraelsen and Hansen, 1962a and Batty et. (l975):**

$$\mathrm{PE} = \mathrm{K}.\frac{\mathrm{A}\,.\,\mathrm{D}\,.\,\mathrm{H}}{\mathrm{Ep.\,Ei}}$$

Where:

PE	=	Pumping energy, (MJ per fed),
K	=	Conversion factor depending on the units used,
A	=	Area irrigated, (fed),
D	=	Net depth of irrigation water requirement,(m),
H	=	Pumping head, (m),
$\mathbf{E_p}$	=	Pumping system efficiency, and
$\mathbf{E_i}$	=	Irrigation efficiency.

Human labor energy:

Energy associated with labor for system operation and management was determined as follows, **(Batty et al., l975):**

$$\mathbf{EHL} = \frac{\mathbf{t\,.\,n\,.\,c}}{\mathbf{A}}\,.\mathbf{NL}$$

Where:

EHL	=	Human labor energy, (Ml per hayr),
t	=	Time of one irrigation, (h),
n	=	Number of irrigation's in year,
C	=	energy input coef. represents human labor energy, 1.26 MJ/man.h,
NL	=	Number oflaborers required for one irrigation, and
A	=	Area irrigated, ha

-Human labor energy inputs associated with operation andcontrol of the water in this study were those ofmanual labor withwater control structures installed represents anegligibleenergy input of less than 0.42 MJ / ha -yr. (Down eta1., 1986).

Energy yield:

The annual yields of crops were calculatedaccording to **Rao and Malik (1982), andCanakci et al. (2005).**

$$\text{Eneregy Intensity}\left(\frac{\text{MJ}}{\text{kg}}\right)=\frac{\text{Total Energy Input}\,(\frac{\text{MJ}}{\text{Fed}})}{\text{Peachegrainyield}\,(\frac{\text{kg}}{\text{fed}})}$$

$$\text{EneregyRatio}=\frac{\text{Totalenergyoutputs}\,(\frac{\text{MJ}}{\text{Fed}}.)}{\text{Totalenergyinputs}\,(\frac{\text{MJ}}{\text{Fed}}.)}$$

$$\text{EneregyProductivty}=\frac{\text{Peachgrainyields}\,(\frac{\text{kgm}}{\text{Fed}}.)}{\text{Totalenergyinput}\,(\frac{\text{MJ}}{\text{Fed}}.)}$$

Net Energy Gain (MJ/ha) = Total Energy Output (MJ/ha) - Total Energy Input (MJ/Ha)

Pumping energy requiremnet depend on assumed the cultivated area was 50 feddan, and 4 basic control valves, so in traditional drip irrigation, the irrigation process was done by opening one vlave not more, and then next valve according to irrigation sheduling. Where in Ulta low-folw irrigation all of 8 vlves were opend during irrigation proces, so the irrigation operating hours were be equal in all of tow drip irrigation.

Energy requirements and energy-applied efficiency **(EAE)** were determined for various drip irrigation systems according to **Batty et. al.,(1975)**,by following formula:

- Power consumption use for pumping water **(B_p)** was calculated ,as follows:

$$Bp=\frac{\text{Q}*\text{TDH}*\text{Yw}}{\text{E i}*\text{Ep}*1000}$$

Where:

Q	=	Total system flow r ate (m^3),
TDH	=	Total dynamic head (m),
E_i	=	Total system efficiency,
E_p	=	Pump efficiency, and
Y_w	=	Water specific weight (taken as 9810 N/m^3).

Pumping energy requirements **(E_r) (kW.h)** was calculated as follows:

$$\mathbf{E_r = B_p \times H}$$

Where:

H = Irrigation time per season (h).

- Pumping energyappliedefficiency **(EAE)** was calculated as follows:

$$EAE(kg/kW)=\frac{\text{Total fresh yield (kg)}}{\text{Energy requirements (kW.h)}}$$

III. Results And Discussions

Power consumptive use for pumping water (Bp, kW) and energy requirements for SMD (surface micro drip irrigation system) and SSMD (subsurface micro drip irrigation system) irrigation systems is lower than SD (surface drip irrigation system) and SSD (subsurface drip irrigation system) irrigation systems according to the reduction of pumping flow under SMD and SSMD, because micro flow does not need high capacity of pumping flow, as well as the energy requirements of SSMD and SD irrigation systems is lower than these obtained under SD and SSD irrigation systems by 55%, as shown in Fig. (2).

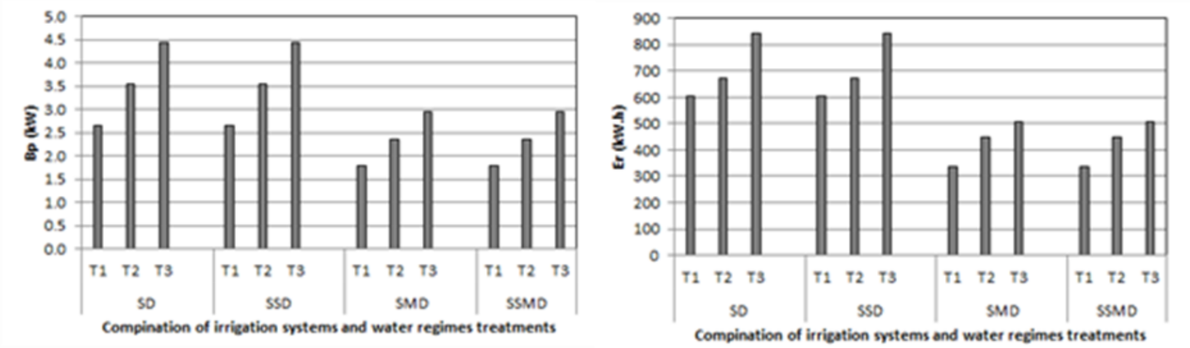

Fig. (2): Power consumption use for pumping water (Bp) and energy requirements (Er) under different irrigation water for pumping different irrigation water treatments.

irrigation systems, as a result of the variation of energy requirements and productivity which gained under SMD and SSMD irrigation systems, at the two growing successful seasons, Fig (3).

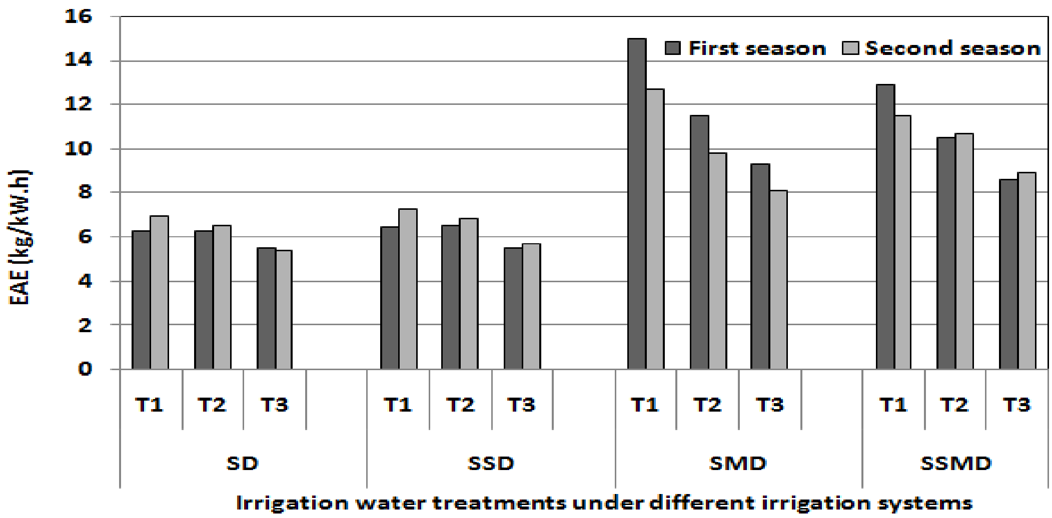

Fig. (3): Energy productivity, (kg/MJ), for applied water, A.I.E.I. (MJ/M3-yr.)for water applied treatments under SSMD, SMD, SSD and SD irrigation system.

Installation energy:

Fig. (4) show that the installation energy for micro drip irrigation systems (SMD and SSMD) was less than traditional drip systems (SD and SSD) by 13.4 % where the average of installation energy of SMD and SSMD irrigation system was 1558 (MJ/ha-yr.), while for SD and SSD irrigation system was 1800 (MJ/ha-yr.). Saving installation energy of SMD andSSMD irrigation systems was a result of saving installationenergy elements like Annual fixed energy (AFE), (MJ/kg-yr.), depending on light weights of irrigation systems elements such as the weight of used polyethylene pipes for SMD and SSMD were 42 kg/fed., but for SD and SSD irrigation systems was doubled (84 kg/ha), the other elements have the same trend, and the required energy for manufacturing equipment or machinery, the required energy for fuel consumption, the required energy for the repairs and maintenance and human labor energy depend on the quantity and weight of used material to install irrigations systems.

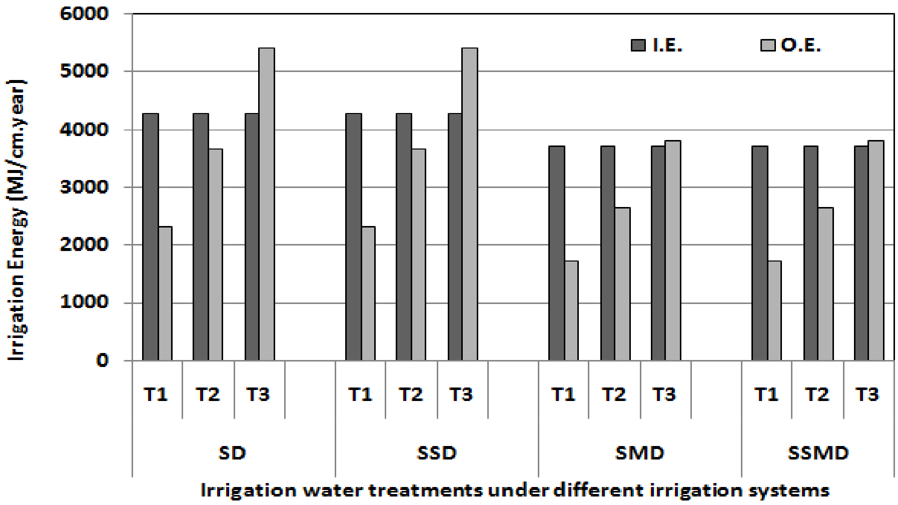

Fig. (4): Installation and operation required energy for SSMD, SMD, SSD and SD irrigation systems under different water applied treatments.

Operation energy:

The energy inputs to operate different irrigation systems including maintenance, pumping energies and human labor energy were 970.91, 1540.45 and 2274.42 (MJ/Ha-yr) for SD and SSD irrigation systems under various water treatments applied T1, T2 and T3 respectively, and were 729.50, 1108.97 and 1108.97 (MJ/Ha-yr) for SMD and SSMD irrigation systems under various water treatments applied T1, T2 and T3, respectively. In the same concern, the average of operation energy inputs of SD and SSD is higher than SMD and SSMD irrigation systems by 28.2 %, for that the micro irrigation system saved the inputs of energy operation by 28.2%. Data in Fig. (3) show that the reduction of energy inputs was obtained by reducing the applied water quantity. As well as there was saving of energy inputs by using SMD and/or SSMD, because the flow of these two systems was 1 l/h, so four valves were opened under the aforementioned irrigation systems to complete the irrigation process in a certain time depending on the applied water quantity, on the other hand only one valve was opened under SD and/or SSD irrigation systems to complete the irrigation process to apply the same quantity of water.

Energy yield:

Annual total irrigation energy inputs for applying water:

Annual total irrigation energy inputs for applying water, refers to the total energy inputs of applied water under various irrigation systems (A.I.E.I) ncreased by the increasing of the applied water. The highest value of A.I.E.I. was 0.19 (MJ/M3-yr.) under SD and SSD for the highest water treatment, while the lowest value was 0.13 (MJ/M3-yr.) under SMD and SSMD irrigation systems for the same water treatment (Table, 3).

Table (3):Energy applied efficiencies for surface drip (SD), subsurface drip (SSD), and surface micro drip (SMD) and sub-surface micro drip (SSMD) under the application of different irrigation water treatments.

Type of energy requirements		SD			SSD		
		T_1	T_2	T_3	T_1	T_2	T_3
A.T.E.I.		6595	7950	9697	6595	7950	9697
A.W.U		34543	46058	57572	34543	46058	57572
A.I.E.I.		0.19	0.17	0.17	0.19	0.17	0.17
R.E.C.	**1st season**	0.879	0.788	0.873	0.708	0.763	0.878
	2nd season	0.788	0.758	0.896	0.631	0.727	0.847

E.E.C.I.	**1st season**	0.462	0.415	0.46	0.372	0.401	0.462
	2nd season	0.415	0.399	0.472	0.332	0.383	0.446
EP	**1st season**	1.138	1.269	1.145	1.413	1.311	1.139
	2nd season	1.269	1.319	1.116	1.586	1.376	1.18
NEG	**1st season**	2.43	2.65	2.44	2.84	2.71	2.43
	2nd season	2.64	2.71	2.38	3.02	2.78	2.5
Type of energy requirements		**SMD**			**SSMD**		
		T_1	**T_2**	**T_3**	**T_1**	**T_2**	**T_3**
A.T.E.I.		5444	6347	7509	5444	6347	7509
A.W.U		34543	46058	57572	34543	46058	57572
A.I.E.I.		0.16	0.14	0.13	0.16	0.14	0.13
R.E.C.	**1st season**	0.515	0.602	0.526	0.565	0.653	0.452
	2nd season	0.606	0.693	0.59	0.554	0.631	0.534
E.E.C.I.	**1st season**	0.271	0.317	0.277	0.297	0.344	0.238
	2nd season	0.319	0.365	0.31	0.292	0.332	0.281
EP	**1st season**	1.94	1.66	1.903	1.771	1.532	2.212
	2nd season	1.652	1.443	1.696	1.805	1.585	1.873
NEG	**1st season**	3.3	3.09	3.27	3.18	2.97	3.45
	2nd season	3.07	2.88	3.12	3.21	3.02	3.26

A.T.E.I= Annual total irrigation energy inputs,(MJ/ha-yr)
A.W.U. = Annual water used, (m^3/ha-yr),
A.I.E.I= Annual total irrigation energy inputs for applied water (MJ/M^3-yr.).
R.E.C. = Relative consumed energy,(MJ/kg),
E.E.C.I= Energy efficiency of crop irrigation, (%),
EP= Energy productivity, (kg/MJ), and
NEG= Net Energy Gain (MJ/Fed).

Generally, data in Table (3) indicated that the values of the annual irrigation energy input (AIEI) increased by increasing the irrigation water quanity, and these values were decreased by using SMD and/or SSMD, moreover all values of EECI, NEG, and REC had the same trend, except under SD irrigation system.

IV. CONCLUSION

SSMD and SMD irrigation system were more economical comparing with SD and SSD irrigation systems, because the energy applied efficiency of SMD and SSMD irrigation systems was higher than SD and SSD irrigation systems. Average net energy gain under SMD and SSMD irrigation system under water treatments is higher than the average net energy gain for SD and SSD irrigation systems for different studied water treatments. The peache production unit of irrigation costs more under SSD and SD irrigation systems was doubled comparing with SSMD and SMD.

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