ENERGY REQUIREMENT AND ECONOMIC ANALYSIS OF SUBSURFACE DRIP IRRIGATION IN SIWA OASIS

Awady[1], M. N., M. A. Wassif[2], M. F. Abd el-Salam[3], and M. A. El-Farrah[4]

ABSTRACT

The aim of this investigation is to evaluate the consumed energy under surface and subsurface drip irrigation techniques in hyper arid condition of Siwa Oasis with using low quality water. Experimental treatments were done at Siwa Oasis – Matruh Governorate. The experimental results showed that energy applied efficiency (EAE, 1.75 kg/MJ), and without escalation (with escalation) benefit/cost ratio 6.16 (5.60) were obtained from with underneath PE sheet, at 10 cm dripline depth, 0.9 – 1.2 m dripline spacing, and VSL (two Vertically Spaced Line) arrangement.

Key words: *Drip irrigation, Subsurface drip irrigation, Dripline spacing, Dripline depth, Underneath sheet, Irrigation economic analysis, Energy applied efficiency, Tomato, and Onion.*

INTRODUCTION

The increased use of trickle or drip irrigation is seen as one way of helping to improve the sustainability of irrigation systems around the world. So, it is useful to get tools, which allow the maximum benefit and minimum disadvantages from these methods. The sustainability of the projects depends on the compatibility with the economic roles.

The use of saline water for agricultural irrigation is attractive for the following reasons: a) Water shortage problems can be resolved; b) Large amounts of saline water can be disposed of during the entire year, with minimal risk of groundwater deterioration; c) Economic benefits: a higher market price for the fruits, which are sweeter, and an extended shelf life, due to the stressful growing conditions **(Oron *et al.*, 1995).**

Using subsurface drip irrigation SDI increasers water use efficiency and its conservation, **(Camp** and **Lamm, 2003),** moreover,

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(1) and (3) resp. Prof. Emerit. and Assoc. Prof., Ag. Eng. Dep., A. Shams U., Cairo, Misr (Egypt).

(2) and (4) resp. Prof.. Emerit. and Res., Soil Conserv. Dep., Desert Res. Center., Cairo, Misr (Egypt).

using SDI enhances the emission uniformity (EU), **(Aboamera, 1999), Shawky *et al.* (2001)** and **Enciso *et al.* (2005).** Consequently, increasing EU of drip irrigation decreased the irrigation water requirements for crops. This means that saving irrigation water and energy required for irrigation could be obtained by increasing the designed water emission uniformity of trickle irrigation system, **(El-Ansary *et al.*, 1999).** And this is in agreement with **Keller** and **Bliesner (1990), Oron *et al.* (1995),** and **Bakeer (1996).** The trickle irrigation has a potential for reducing pumping energy costs where operating pressure are considerably lower than that of the other pressurized systems types, **(Bucks** and **Nakayama, 1982)** and this is in agreement with **Abd Elaal, (1991),** who also concluded that drip irrigation system obtains higher energy application efficiency (EAE) compared to the other systems.

Low operating pressure value, where the emitter operating pressure head 5 – 8 m is suitable for fodder and vegetable production, **(El-Berry, 1990).** Furthermore, the converting to low-pressure emitter type may reducing irrigation consumed, **(Evans *et al.*, 1996).**

Kassem and **Mulhim (1999)** showed that estimating net irrigation requirements are useful in determining pumping requirements, and hence the energy needs.

Barth (1995) found that the economical advantages of the SDI are savings in water and energy as well as significant improvements in crop yield. He added that the subsurface irrigation has productivity rates between 30 to 70 % above surface irrigation methods. Further economic factors are influencing the social situation and minimize maintenance. Due to the subsurface layout, the laterals are not as exposed to damage and a fully mechanized labor saving operation is possible. Moreover, management problems are reduced to a minimum due to the simplicity of the system.

Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution reduction, **(Pervanchon *et al.*, 2002).** Energy analysis can be divided into two parts as direct and indirect energy, **(Uhlin, 1998).** Direct energy is directly used at the farm and on fields for crops, but indirect energy is not directly consumed at the farm. However, both direct and indirect forms of energy are required for agricultural production in terms of its development and growth. On the other hand, despite its importance, energy use can be very costly. Energy input output analysis is usually used to evaluate the efficiency and environmental impacts of production systems, **(Ozkan et al., 2003).**

Annual irrigation costs must include all costs associated with owning and/or renting, operating and maintaining the irrigation system, **(Thompson *et al.*, 1983).** They also illustrated that the fixed and variable costs associated with owning and operating an irrigation system have increased for a number of years and are projected to continue to increase in the future and this known as **cost escalation (inflation)**.

It is worth, that the ideal general planning of irrigation system consists of lateral lines and submain lines and main line and these groups come out an area, which can be repeated, **(Awady, 1974).**

The most economical size for irrigation main line depends only the irrigated area and not on the pipe length. A relationship was expressed in the very applicable form “$D = 20.16\sqrt{A}$” where “D” is the pipe diameter in mm and “A” is the irrigated area by fed, **(El Awady** and **Hegazi, 1987).**

Another theory for selecting the optimal pipe size of trickle irrigation system based on water velocity by **Hassan** and **Younis (1987).** They found that optimal water velocity varied between 0.5 – 1.0, 1.0 – 1.5, and 0.5 – 1.5 m/s for lateral, submain, and main line, respectively.

In addition, computer model can be developed to help in selecting drip irrigation optimal design. The solution based upon minimum total annual cost for specific statistical uniformity. And the availability of determining the optimal area of trickle irrigation submain unit can be obtained. It is easy to get results, which are comprehensive technical and economic details for the owner or designer about the system to evaluate the economic soundness, **(Sharaf, 1996).**

MATERIALS AND METHODS

* Site of the experiment:

Two field experiments were conducted during winter season (2006 – 2007) in Agricultural Experiment Station of the Desert Research Center (DRC), Siwa oasis – Mersa Matruh Governorate. Siwa depression is located on the northern edge of the great sand sea, one of the largest sand areas in the world in the western desert of Egypt at about 750 km north west of Cairo and 300 km west south Mersa Matruh (The Mediterranean coast). Depression has a length of about 75 km and a width varying between 5 and 25 km with a total area of about 1088 km^2. The elevation of the floor is 0 to -18 m from sea level and the longitude ranges between $25^o18' - 26^o$ E and the latitude ranges between $29^o5' - 29^o20'$ N.

The soil of experiments is deeply sand. It is a part of sand dune, which is very deep and the water table surface is about 4 m depth.

Irrigation system installation and experimental treatments:

The first experiment (E_1) without PE foil was carried out including the following treatments:

a. Two Adjacent Lines (AL) and two Vertically-Spaced Line (VSL) at 15 cm in-between.
b. Variation in driplines depth ((upper dripline of VSL or AL depth was 0 and 10 cm).
c. Variation in the driplines spacing (0.4 to 1.0 m).

The main treatment was the driplines arrangement (AL or VSL). Sub-main treatments were the dripline depth (D = 0 or 10 cm) and, variation of dripline spacing (S from 0.4 to 1.0 m), as shown in Fig. (1).

It is worth to mention that using 15 cm Vertically-Spaced driplines in VSL conforms to **Ismail *et al.* (2006)**.

The second experiment (E_2) had underneath PE foil, with the following treatments:

a- Dripline arrangement (AL and VSL).
b- Variation in driplines depth (upper dripline in VSL or AL depth was varied from 0 to 25 cm).
c- Variation of the driplines spacing (0.2 to 1.2 m).

Each treatment was replicated two times. Each lateral dripline was considered as one replicate for the plant grown, so the plant yield of each crop was obtained from four replicates.

All plots received the same amount of organic manure (about 4 m^3/fed) without any chemical fertilizer.

The intercropping yields of tomato and onion were conducted. Tomato seedlings (Super strain B, Lycopersicon esculentum L.) with plant spacing 0.5 m of dripline and onion seedlings (Yellow creol, Allium cepa) with plant spacing 0.1 m of dripline, were sown on 3/1/2007. Two croppings were obtained and recorded for each experiment and each treatment.

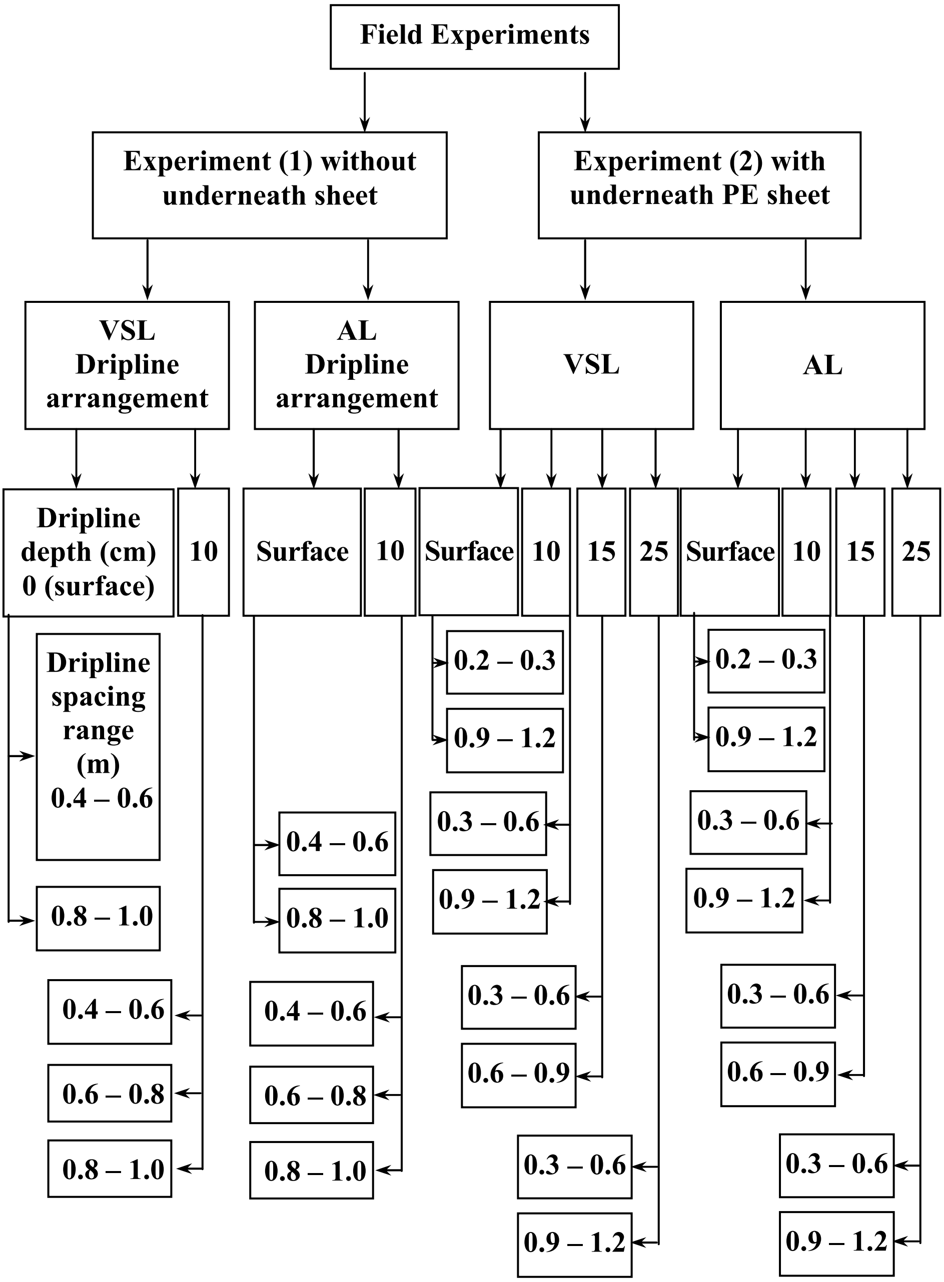

Fig. (1): Flow chart of the experimental treatments.

*** Energy consumption:**

Work is required to lift and pressurized water and amount of water delivered per unit time can be related to power and the energy applied efficiency (EAE) according to **Abedel-Aal (2000)**:

$$B_p = \frac{Q \times H_D \times Y_W}{E_i \times E_p \times 1000} \text{ .... } \mathbf{(1)}$$

Where: B_p: Brake power (kW)
Q : Discharge (m^3/sec)
H_D: Total dynamic head (m)
E_p: Pump efficiency
Y_W: Water specific weight (9810 N/m^3)
E_i: Irrigation efficiency

Pumping energy requirement (E_r) = B_p × T .... (2)

Where, T: Irrigation time per season for area unit, (h/fed)

Total energy requirements, E_{tr} (kW.h/fed) **= E_r + E_{in} (E_{tr}) ..... (3)**

Where, E_{in} Laterals installation energy consumed (MJ), and it was determined as man energy per hour equals to 1.96 MJ according to **Ozkan *et al.* (2003)**. The consumed time in the installing depends on (dripline arrangement, dripline depth, and dripline spacing).

$$\textbf{Energy applied efficiency (EAE)} = \frac{\textbf{Total Yield (kg/fed)}}{\mathbf{E_{tr}}\textbf{ (kW.h/fed)}} \text{ ... } \mathbf{(4)}$$

*** Economic analysis:**

The following equations were used to compute the annual **fixed cost** by the application of an amortization factor, **(Thompson *et al.*, 1983** and **James, 1988).** Present worth (PW) is the amount of cost that must be invested at the beginning of the analysis period. When the analysis period equals the component useful life (assumed), and it can compute by:

$$PWF = (1 + ir)^{-LF} \text{ .... } \mathbf{(5)}$$

$$PW = (IC) \times (PWF) = IC \times (1 + ir)^{-LF} \text{ ...... } \mathbf{(6)}$$

The present worth value if there is salvage value at the end of useful life:

$$PW = IC - SV\left[\frac{1 + er}{1 + ir}\right]^{LF} \text{ ..... } \mathbf{(7)}$$

$$CRF = \frac{ir(1+ir)^{LF}}{(1+ir)^{LF} - 1} \text{ ..... } \mathbf{(8)}$$

The fixed cost for all components can compute by:

$$AFC = CRF \sum_{c=1}^{c=n} PW_c \text{ ...... } \mathbf{(9)}$$

The **escalation effect** on the present worth factor:

$$PWF_{(r)} = \frac{(1+er)^{LF}}{(1+ir)^{LF}} = \left(\frac{1+er}{1+ir}\right)^{LF} \text{ ... } \mathbf{(10)}$$

$$PW_{(r)} = (IC) \times (PWF_{(r)}) = IC \times \left(\frac{1+er}{1+ir}\right)^{LF} \text{ ... } \mathbf{(11)}$$

$$EAF_{(r)} = \left[\frac{(1+er)^{LF} - (1+ir)^{LF}}{(1+er) - (1+ir)}\right] \times \left[\frac{ir}{(1+ir)^{LF} - 1}\right], \text{ for er} \neq \text{ir .. } \mathbf{(12)}$$

Where: AFC: Annual fixed cost (amortization value)
CRF: Capital recovery factor
PWF: Present worth factor
$PWF_{(r)}$: Present worth factor with escalation
PW: Present worth of component “c” (L.E)
$PW_{(r)}$: Present worth of component with escalation “c” (L.E)
EAF: Uniform equivalent annual cost factor
EAC: Uniform equivalent annual cost.
n: Number of system component
LF: Estimated life (year)
ir: Annual interest rate (decimal)
IC: Initial cost of component or replacement cost
SV: Salvage value of component
er: Expected annual rate of cost escalation.

*** Laterals and submain initial cost were estimated as follows:**

$$IC_L = N \times \left[(L \times LUC) + (ne \times EC)\right] \text{.... } \mathbf{(13)}$$

$$IC_S = (N-1) \times \left[(SL \times SUC) + TC\right] \text{..... } \mathbf{(14)}$$

Where: IC_L: Lateral hose initial cost (L.E)

LUC: Price of lateral hose unit length (L.E/m)

EC: Price of emitter (L.E/unit)

IC_S: Submain line initial cost (L.E)

SUC: Price of manifold unit pipe length (L.E/m)

L: Lateral length (m)

SL: Lateral spacing (m)

N: Number of laterals (unit)

ne: Number of emitters (unit)

TC: Price of grommet or tee connection (L.E/unit).

Where the emitter in the GR dripline is not a separate part and it fixed in the line then the equation (3.20) becomes as following:

$$IC_L = N \times (L \times LUC) \text{ ...... } \mathbf{(15)}$$

It is worth to mention that the cost of installing the irrigation system or parts can be calculated as a fixed cost and added to the total fixed cost.

The **variable operation costs** which contains:

- Energy cost:

$$AEC = Bp \times T_i \times C_{kw} \text{ ...... } \mathbf{(16)}$$

Where: AEC: Annual energy cost (L.E/year)

T_i: Irrigation operating time (h/year)

C_{kw}: Cost of energy (L.E/kW.h).

- Maintenance and repair cost:

$$LMR = N\,(L \times LUC \times MR_{PP}) \text{ .... } \mathbf{(17)}$$

$$SMR = IC_S \times MR_{PP} \text{ ...... } \mathbf{(18)}$$

$$PMR = IC_P \times MR_P \text{ ...... } \mathbf{(19)}$$

Where: LMR: Laterals maintenance and repair cost (L.E)

SMR: Submain line maintenance and repair cost (L.E)

PMR: Pump maintenance and repair cost (L.E)

MR_{PP}: Annual maintenance and repair for plastic pipe (decimal)

MR_P: Annual maintenance and repair for pump (decimal)

IC_P: Pump initial fixed cost (L.E).

Maintenance and repair guidelines for trickle irrigation components (Jensen, 1983) showed that annual maintenance and repair ratio of initial cost were 3 – 5, 5 – 8, 1.5 – 2.5, and 5 – 8 % for centrifugal pump, diesel engine, plastic pipe, and trickle emitters, respectively.

- Labor cost:

The cost of operating time, which is consumed in operate and check the component. Labor cost is estimated by following:

$$ALC = T_i \times LC \quad \textbf{.... (20)}$$

Where: ALC: Annual labor cost (L.E)
T_i: Annual irrigation time (h/year)
LC: Labor cost (L.E/h).

RESULTS AND DISCUSSIONS

* Energy Applied Efficiency (EAE):

Treatments without underneath sheet: The yield of intercropping *(tomato and onion)* per consumed energy for the different treatments without underneath sheet is illustrated in, Tab. (1). It is clear that the high EAE value was 0.76 kg/MJ for all dripline spacing of dripline depth 10 cm under VSL.

The total seasonal energy is a part of annual energy depending on the season consumed time. Season time was 5 months thus the annual energy will be converted to seasonal energy per feddan. The seasonal energy was affected by the variation in treatment factors. Tab. (1), represents the total energy, and the energy components. It is clear that the highest energy component was the irrigation energy which was affected mainly by the dripline spacing then the water quantity per feddan. The energy of farmyard manure was high because it has high specific energy per weight 0.3 MJ/kg, **(Ozkan *et al.* 2003).** On the other hand, the installation energy was low because it resulted from dividing the total installation energy by the component life time. The energy of harvesting and transportation depended directly on the production quantity of the treatment.

According to mean energy components, irrigation energy is the highest component followed by farmyard manure energy and the next protection of plant against sand hazards and the minimum energy value was for transportation.

Table (1): Energy components and total energy without underneath sheet.

Dripline arrangement	Dripline depth (cm)	Dripline spacing (m)	Yield (kg/fed)	Irrigation energy (MJ/fed)	Installing energy (MJ/fed)	Farm yard manure energy (MJ/fed)	Protection energy (MJ/fed)	Cultural practices energy (MJ/fed)	Harvesting energy (MJ/fed)	Transportation energy (MJ/fed)	Total Energy (MJ/fed)	Yield energy ratio (kg/MJ)
VSL	surface	0.4 - 0.6	2996	4964	38	501	305	261	48	28	6145	0.488
		0.8 - 1.0	1554	2782	19	251	152	131	25	14	3374	0.461
	10	0.4 - 0.6	4793	4964	89	501	305	261	77	44	6241	0.768
		0.6 - 0.8	3334	3545	55	309	188	161	53	31	4343	0.768
		0.8 - 1.0	2648	2782	44	251	152	131	42	24	3427	0.773
AL	surface	0.4 - 0.6	3035	4964	38	501	305	261	49	28	6146	0.494
		0.8 - 1.0	1162	2782	19	251	152	131	19	11	3364	0.346
	10	0.4 - 0.6	2872	4964	89	501	305	261	46	26	6192	0.464
		0.6 - 0.8	2741	3545	55	309	188	161	44	25	4329	0.633
		0.8 - 1.0	1828	2782	44	251	152	131	29	17	3406	0.537

EAE increased with using underneath PE sheet, where EAE value under VSL arrangement was 1.74 kg/MJ for dripline spacing range 0.9 – 1.2 m, at 10 cm dripline depth, Tab. (2). The installation energy increased as compared to without underneath PE sheet due to the installing of PE sheet increasing excavation, which increases consumed energy. The highest irrigation energy was associated with dripline spacing range of 0.2 – 0.3 m due to the high amount of irrigation water per unit area compared with the other dripline spacing ranges. The protection energy is inversely proportion with dripline spacing but with small difference between the treatments.

The economic analysis of irrigation system:

The previous parts are converted here as a benefit and cost. Solving the disposal of drainage water problem in Siwa oasis has a lot of benefits, which are considered indirect benefits. This part will focus only on the direct benefits and costs. As mentioned before, the cost consists of fixed and annual (energy, maintenance and labor) costs. The calculation was based on that life time for the plastic lines (driplines) is 5 and 10 years according to exposure to sunshine. It is assumed that the annual interest rate (ir) and expected annual rate of cost escalation or inflation (er) are 10 and 8 %, respectively. The plastic pipe salvage equals zero prices after the useful life time. The costs of installation of the irrigation system were added to the fixed cost.

Treatments without underneath sheet: The annual cost per feddan is affected by the treatments, where the differences in the treatments led to varying the system size, and then the price. The assumed price for different fittings is shown in Table (3). The results without inflation (with inflation) without underneath sheet treatment, showed that the highest treatment costs were 7526 (12358) and 5630 (8208) L.E/year, which represent the surface driplines with spacing 0.4 – 0.6 m under AL and VSL, respectively, Fig. (9). This may be attributed to the small dripline spacing, which led to a lot of lateral dripline and big size of manifold. In addition, surface driplines led to short life time (5 years) due to sunshine (ultra violet) exposure and then enlarging the fixed cost resulted from replacing the expired parts.

Table (2): Energy components and total energy with underneath PE sheet.

Dripline arrangement	Dripline depth (cm)	Dripline spacing (m)	Yield (kg/fed)	Irrigation energy (MJ/fed)	Installing energy (MJ/fed)	Farm yard manure energy (MJ/fed)	Protection energy (MJ/fed)	Cultural practices energy (MJ/fed)	Harvesting energy (MJ/fed)	Transportation energy (MJ/fed)	Total Energy (MJ/fed)	Yield energy ratio (kg/MJ)
VSL	Surface	0.2 - 0.3	6555	9873	183	601	366	314	105	60	11502	0.57
		0.9 - 1.2	1110	2509	65	215	131	112	18	10	3060	0.36
	10	0.3 - 0.6	5331	5400	254	501	305	261	85	49	6856	0.78
		0.9 - 1.2	5590	2509	109	215	131	112	89	51	3216	1.74
	15	0.3 - 0.6	5882	5400	292	501	305	261	94	54	6908	0.85
		0.6 - 0.9	4052	3273	175	301	183	157	65	37	4191	0.97
	25	0.3 - 0.6	2917	5400	343	501	305	261	47	27	6884	0.42
		0.9 - 1.2	1229	2509	147	215	131	112	20	11	3145	0.39
AL	Surface	0.2 - 0.3	4276	9873	183	601	366	314	68	39	11444	0.37
		0.9 - 1.2	2106	2509	65	215	131	112	34	19	3085	0.68
	10	0.3 - 0.6	6926	5400	254	501	305	261	111	64	6896	1.00
		0.9 - 1.2	2785	2509	109	215	131	112	45	26	3146	0.89
	15	0.3 - 0.6	6201	5400	292	501	305	261	99	57	6916	0.90
		0.6 - 0.9	1659	3273	175	301	183	157	27	15	4130	0.40
	25	0.3 - 0.6	3497	5400	343	501	305	261	56	32	6898	0.51
		0.9 - 1.2	1080	2509	147	215	131	112	17	10	3141	0.34

The variation in the cost value between the two arrangement VSL and AL according to the VSL arrangement has one dripline on the surface and another subsurface, while in AL arrangement both driplines were at the surface. In contrast, minimum treatment costs were 2333 (2566) and 2366 (2599) L.E/year under 10 cm dripline depth with 0.8 – 1.0 m dripline spacing under AL and VSL, respectively. This is attributed to that price of installing VSL laterals was higher than that of AL at the same depth because the total depth in VSL was deeper than that in AL by 15 cm.

The total season cost is a part of annual cost depending on the season consumed time. Season time was 5 month thus the annual cost will be converted to season cost per feddan. The season cost is affected by the variation in treatments. Tab. (4) represents the benefits of intercropping yields, total cost, and the cost components in the case without inflation. It is clear that the highest cost component was the fixed cost in all treatments.

Table (3): The assumed price for irrigation system fittings and crop in 2006.

Fitting	Dia. (mm)	Unit	Price (L.E)
Plastic pipes (PVC)	50	m	4.4
	63	m	5.8
	110	m	17
	125	m	21
	140	m	25
	160	m	35.45
GR lateral	16	m	0.6
Total length of pipe (m) in Ex. station	125	m	703
Total experimental serviced area (fed)		fed	25
Related part with fed	125		28.12
Price of Pump		No.	20000
Related price part with fed (pump)			800
Energy price:			
1 kW.h		kW.h	0.066
Crop price:			
Tomato		kg	1
Onion		kg	1

Table (4): Cost components, total cost, the benefit of treatments without underneath sheet at year's 2006.

Escalate	Dripline arrangement	Dripline Depth (cm)	Dripline spacing (m)	Cost L.E/season					Benefit (L.E/season)	Ratio	System cost (L.E/year)
				Fixed	Energy	Maintenance	Labor	Total			
Without	VSL	Surface	**0.4 - 0.6**	1971	91	190	94	2346	2996	1.28	5630
			0.8 - 1.0	1159	51	122	94	1426	1554	1.09	3422
		10	**0.4 - 0.6**	1172	91	190	94	1547	4793	3.10	3713
			0.6 - 0.8	832	65	139	94	1130	3334	2.95	2712
			0.8 - 1.0	719	51	122	94	986	2648	2.69	2366
	AL	surface	**0.4 - 0.6**	2761	91	190	94	3136	3035	0.97	7526
			0.8 - 1.0	1598	51	122	94	1865	1162	0.62	4476
		10	**0.4 - 0.6**	1155	91	190	94	1530	2872	1.88	3672
			0.6 - 0.8	815	65	139	94	1113	2741	2.46	2671
			0.8 - 1.0	705	51	122	94	972	1828	1.88	2333
With	VSL	Surface	**0.4 - 0.6**	2908	125	259	128	3420	2996	0.88	8208
			0.8 - 1.0	1681	69	167	128	2045	1554	0.76	4908
		10	**0.4 - 0.6**	1172	125	259	128	1684	4793	2.85	4042
			0.6 - 0.8	832	89	189	128	1238	3334	2.69	2971
			0.8 - 1.0	719	69	167	128	1083	2648	2.45	2599
	AL	surface	**0.4 - 0.6**	4637	125	259	128	5149	3035	0.59	12358
			0.8 - 1.0	2644	69	167	128	3008	1162	0.39	7219
		10	**0.4 - 0.6**	1155	125	259	128	1667	2872	1.72	4001
			0.6 - 0.8	815	89	189	128	1221	2741	2.24	2930
			0.8 - 1.0	705	69	167	128	1069	1828	1.71	2566

The season cost is affected by inflation plus the variation in treatments. Tab. (4) represents the benefits and cost components. It is clear that the inflation enlarges the fixed cost especially in the surface treatments in both AL and VSL.

According to mean cost components, fixed cost is the highest component followed by maintenance cost and next the labor cost and at last the energy cost. It is clear that the inflation effects proportional with the component value.

The benefit from crops yield per total cost ratio is shown in Tab. (4). Dripline depth of 10 cm shows superiority in both VSL and AL. These results are in agreement with **Keller** and **Bliesner (1990), Barth (1995)**, and **Oron *et al.* (1995).** Without inflation (with inflation) high profit ratio values were 2.69 (2.45), 2.95 (2.69), and 3.10 (2.85) for dripline spacing ranges 0.8 – 1.0, 0.6 – 0.8, and 0.4 – 0.6 m, respectively with 10 cm dripline depth and under VSL. The surface driplines gave low ratio values in both arrangements.

In the treatment of with underneath PE sheet, the highest treatment costs without inflation (with inflation) were 13961 (25646) and 10102 (15122) L.E/year, which represent the surface driplines with dripline spacing range 0.2 – 0.3 m under AL and VSL, respectively, Tabs. (5 and 6). This may be attributed, as mentioned previously to replacement costs of laterals for surface case. In contrast, minimum costs were 2124 (2342) and 2179 (2397) L.E/year, under 10 cm dripline depth, with 0.9 – 1.2 m dripline spacing, and under AL and VSL, respectively. It is clear that the highest component cost was the fixed cost followed by maintenance cost, next the labor cost and last the energy cost. In addition, the inflation enlarges the fixed cost, especially in the surface treatments in both AL and VSL arrangement.

The benefit price from crops yield per total cost ratio is shown in Tabs. (5 and 6). Dripline depth of 10 cm was superior in both VSL and AL arrangement. The highest profit ratio without inflation (with inflation) were 3.54 (3.26), 3.69 (3.37), and 6.16 (5.60) for dripline spacing ranges 0.3 –0.6, 0.6 – 0.9, (15 cm dripline depth), and 0.9 – 1.2 m (10 cm dripline depth), respectively under VSL arrangement.

Table (5): Cost components, total cost, the benefit of treatments with PE underneath sheet without inflation at year's 2006.

Dripline arrangement	Dripline depth (cm)	Dripline spacing (m)	Cost L.E/season					Benefit (L.E/season)	Ratio	System cost (L.E/year)
			Fixed	Energy	Maintenance	Labor	Total			
VSL	**surface**	**0.2 - 0.3**	3617	181	317	94	4209	6555	1.56	10102
		0.9 - 1.2	1046	46	110	94	1296	1110	0.86	3110
	10	**0.3 - 0.6**	1260	99	202	94	1655	5331	3.22	3972
		0.9 - 1.2	658	46	110	94	908	5590	6.16	2179
	15	**0.3 - 0.6**	1265	99	202	94	1660	5882	3.54	3984
		0.6 - 0.9	811	60	133	94	1098	4052	3.69	2635
	25	**0.3 - 0.6**	1293	99	202	94	1688	2917	1.73	4051
		0.9 - 1.2	669	46	110	94	919	1229	1.34	2206
AL	**surface**	**0.2 - 0.3**	5225	181	317	94	5817	4276	0.74	13961
		0.9 - 1.2	1034	46	110	94	1284	2106	1.64	3082
	10	**0.3 - 0.6**	1243	99	202	94	1638	6926	4.23	3931
		0.9 - 1.2	635	46	110	94	885	2785	3.15	2124
	15	**0.3 - 0.6**	1254	99	202	94	1649	6201	3.76	3958
		0.6 - 0.9	797	60	133	94	1084	1659	1.53	2602
	25	**0.3 - 0.6**	1265	99	202	94	1660	3497	2.11	3984
		0.9 - 1.2	658	46	110	94	908	1080	1.19	2179

Table (6): Cost components, total cost, the benefit of treatments with PE underneath sheet with inflation.

Dripline arrangement	Dripline depth (cm)	Dripline spacing (m)	Cost L.E/season					Benefit (L.E/season)	Ratio	System cost (L.E/year)
			Fixed	Energy	Maintenance	Labor	Total			
VSL	0	0.2 - 0.3	5494	247	432	128	6301	6555	1.04	15122
		0.9 - 1.2	1515	63	150	128	1856	1110	0.60	4454
	10	0.3 - 0.6	1260	135	275	128	1798	5331	2.96	4315
		0.9 - 1.2	658	63	150	128	999	5590	5.60	2398
	15	0.3 - 0.6	1265	135	275	128	1803	5882	3.26	4327
		0.6 - 0.9	811	82	182	128	1203	4052	3.37	2887
	25	0.3 - 0.6	1293	135	275	128	1831	2917	1.59	4394
		0.9 - 1.2	669	63	150	128	1010	1229	1.22	2424
AL	0	0.2 - 0.3	9879	247	432	128	10686	4276	0.40	25646
		0.9 - 1.2	1503	63	150	128	1844	2106	1.14	4426
	10	0.3 - 0.6	1243	135	275	128	1781	6926	3.889	4274
		0.9 - 1.2	635	63	150	128	976	2785	2.85	2342
	15	0.3 - 0.6	1254	135	275	128	1792	6201	3.46	4301
		0.6 - 0.9	797	82	182	128	1189	1659	1.40	2854
	25	0.3 - 0.6	1265	135	275	128	1803	3497	1.94	4327
		0.9 - 1.2	658	63	150	128	999	1080	1.08	2398

SUMMARY AND CONCLUSIONS

In case of with underneath PE sheet, EAE, the highest value under VSL was 1.75 kg/MJ for dripline spacing range 0.9 – 1.2 m, at 10 cm dripline depth.

In the treatments without underneath sheet, the minimum cost without inflation (with inflation) was 2333 (2566) L.E/year under 10 cm dripline depth with 0.8 – 1.0 m dripline spacing under AL. According to mean cost components, fixed cost had the highest contribution, followed by maintenance cost, labor cost, and at last the energy cost.

From the benefit cost (profit) ratio point of view, 10 cm dripline depth had high ratio at any width either for VSL or AL arrangement. The highest profit ratio without inflation (with inflation) was 3.10 (2.85) for dripline spacing range 0.4 – 0.6 m, with 10 cm dripline depth under VSL arrangement.

In the treatments with underneath PE sheet, the minimum cost without inflation (with inflation) was 2124 (2342) L.E/year, under 10 cm dripline depth, with 0.9 – 1.2 m dripline spacing, under AL. It is clear that the escalation enlarges the fixed cost especially in the surface treatments in both AL and VSL.

From the benefit cost ratio point of view, 10 cm dripline depth had high ratio at any width either for VSL or AL arrangement. The highest ratio values were 6.16 (5.60) without and with inflation for dripline spacing range 0.9 – 1.2 m, with 10 cm dripline depth under VSL arrangement.

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الملخص العربى

إحتياجات الطاقة والإقتصاديات لنظام الري بالتنقيط تحت السطحي بواحة سيوة

أ.د./ محمد نبيل العوضي[1]، أ.د./ محمد عبده وصيف[2]، د./ مصطفى فهيم عبد السلام[3]، د./ محمد عبد الحميد الفره[4]

أجري هذا البحث بمحطة مركز بحوث الصحراء بواحة سيوة – محافظة مطروح، بهدف دراسة التقييم الطاقي والاقتصادي لإستخدام نظام التنقيط تحت السطحي تحت تأثير الأبعاد الهندسية المختلفة لنظام الري في ظروف الواحة ومع إستخدام مياه ذات ملوحة عالية (حوالي 6000 جزء في المليون). وقد إستخدمت شريحة غير منفذة تحت خط التنقيط في بعض المعاملات، وذلك بعرض 50 سم إسفل الخطوط بحوالي 15 سم. وتم إختيار أعماق مختلفة لخط التنقيط (من صفر إلى 25 سم)، ومسافات بين خطوط التنقيط للتجربة الأولى (من 0.20إلى 1.2 م) وللتجربة الثانية (من 0.4 إلى 1.0 م). وأخذ توزيع الرطوبة في قطاع التربة على عمق واحد أوعمقين وذلك بوضع **خطي تنقيط متلازمين** (خ م) **أو مزاحين رأسياً بمسافة 15 سم (خ ر)**، وقيس الناتج المحصولي لكل من الطماطم والبصل، والمنزرعا بأرض رملية، وذلك باستخدام خطوط ري تنقيط (GR) نقاطين/ المتر، بتصرف 8 لتر/س.م عند ضغط واحد بار.

وقد توصلت الدراسة إلى النتائج الآتية:

*** كفاءة تطبيق الطاقة (EAE):**

- تأثرت قيمة الناتج المحصولي بالنسبة للطاقة المستهلكة **(EAE)** لمحصولي الطماطم والبصل بعمق خطوط التنقيط، وترتيب الخطوط وكذلك وجود حاجز تحت التربة من عدمه، ففي حالة عدم وجود حاجز كانت أعلي نسبة (0.77 كج/ميجا جول) تم الحصول عليها لعمق الخطوط 10 سم للحالة "خ ر"، في حين كانت أقل نسبة تم الحصول عليها هي (0.346 كج/ميجا جول) وهي بالحالة "خ م" للخطوط السطحية ذو مدى إتساع 0.8 – 1.0 م.

- في حالة وجود حاجز كانت أعلى نسبة (1.75 كج/ميجا جول) تحت الترتيب "خ ر" ومدى إتساع خطوط قدره 0.9 – 1.2 م والعمق 10 سم، في حين كان أقل نسبة تم الحصول عليها هي (0.337 كج/ميجا جول) وهي بالحالة "خ م" لعمق الخطوط 25 سم ذو مدى الإتساع 0.9 – 1.2 م.

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(1) أستاذ الهندسة الزراعية غ. متفرغ بكلية الزراعة جامعة عين شمس.
(2) أستاذ الأراضي المتفرغ بقسم صيانة الأراضي بمركز بحوث الصحراء.
(3) أستاذ مساعد الهندسة الزراعية بكلية الزراعة جامعة عين شمس.
(4) باحث بقسم صيانة الأراضي بمركز بحوث الصحراء.

مما يشير إلى أن الحاجز أدى إلى تحسين نسبة الناتج المحصولي إلى الطاقة المستهلكة من 0.57 إلى 0.7 كج/ميجا جول، بغض النظر عن باقي المعاملات.

في المعاملات غير المحتوية على حاجز كان ترتيب المفردات من حيث إستهلاك الطاقة من الأعلى إلى الأقل هي الري، السماد العضوي، الحماية (بالتزريب)، العمليات الخاصة بالزراعة، الحصاد، الإنشاء، والنقل، بالترتيب. في حين حدث زيادة واضحة في طاقة الإنشاء في حالة وجود عازل نتيجة زيادة العمق والإتساع للحفر.

وقد إرتبطت طاقة الري وعملية الحماية بالإتساع بين خطوط التنقيط في حين إرتبطت طاقة الإنشاء بعمق وإتساع الحفر وكذلك إرتبطت طاقة الحصاد والنقل بكمية الإنتاج.

*** التحليل الاقتصادي:**

وقد تضمنت التكلفة السنوية لنظام الري والذي تأثر بالمعاملات تحت الدراسة، حيث يؤدي تغيير المعاملات إلى تغيير حجم النظام وكميات المستلزمات ومن ثم التكاليف. وكذلك حساب العائد من المحصول في الموسم والتكاليف للموسم نسبةً إلى السنة. وهذه التكاليف سواء ثابتة أو متغيرة لازمة لامتلاك وتشغيل أنظمة الري والتي تستمر للعديد من السنوات، وعند التخطيط لتغطية هذه التكاليف يلزم زيادتها تبعاً لارتفاع الأسعار وهذا ما يعرف بالتضخم.

- ♦ **في التجربة غير المحتوية على حاجز تحت التربة:**

كانت أقل تكاليف سنوية تم الحصول عليها في حالة عدم وجود تضخم (وجود تضخم) هي 2333 (2566) جنية مصري/السنة.فدان وذلك لعمق الخطوط 10 سم وإتساع بينها 0.8 – 1.0 م في الحالة "خ م"، وهذا يرجع إلى زيادة تكاليف عملية الإنشاء لخطوط التنقيط للحالة "خ ر" مقارنة بالحالة "خ م" عند نفس العمق حيث العمق الكلي في حالة "خ ر" تزيد عن مثيلتها في الحالة "خ م" بمقدار 15 سم. في حين كان أعلى تكلفة سنوية في حالة عدم وجود تضخم (وجود تضخم) هي 7526 (12358) جنية مصري/السنة.فدان والتي كانت بالخطوط السطحية والإتساع بين الخطوط 0.4 – 0.6 م بالحالة "خ م"، حيث يرجع ذلك إلى صغر المسافة بين الخطوط ومن ثم زيادة عدد الخطوط وكبر حجم الموزع وكذلك ساهمت الحالة السطحية للخطوط في زيادة التكاليف حيث سرعة تلفها لتعرضها للأشعة فوق البنفسيجية للشمس، كما يوجد اختلاف أيضاً في التكاليف للخطوط السطحية بين الحالة "خ ر" والحالة "خ م" حيث تتواجد جميع الخطوط السطحية على سطح التربة في الحالة "خ م" في حين يكون نصف الخطوط تحت سطح التربة بالحالة "خ ر".

وبالنسبة لمتوسط التكاليف تمثل التكاليف الثابتة أعلى قيمة يليها تكاليف الصيانة ثم العمالة وأخرها تكاليف الطاقة.

وقد تميز العمق 10 سم في نسبة المنفعة إلى التكاليف في أي إتساع ومع أي حالة سواء "خ ر" أو "خ م"، وكانت أعلى نسبة في حالة عدم وجود تضخم (وجود تضخم) هي 3.1 (2.85) للإتساع بين الخطوط 0.4 – 0.6 م والعمق 10 سم بالحالة "خ ر"، وقد أعطت المعاملات السطحية أقل نسبة.

- **في التجربة المحتوية على حاجز تحت التربة:**

كانت أقل تكاليف سنوية تم الحصول عليها في حالة عدم وجود تضخم (وجود تضخم) هي 2124 (2342) جنية مصري/السنة.فدان وذلك لعمق الخطوط 10 سم وإتساع بينها 0.9 – 1.2 م في الحالة "خ م"، وهذا يوضح أن التضخم يزيد التكاليف بخاصة المعاملات السطحية سواء الحالة "خ ر" أو "خ م". في حين كان أعلى تكلفة سنوية في حالة عدم وجود تضخم (وجود تضخم) هي 13961 (25646) جنية مصري/السنة.فدان والتي كانت بالخطوط السطحية والإتساع بين الخطوط 0.2 – 0.3 م بالحالة "خ م" ويرجع هذا لارتفاع تكاليف الإحلال.

وقد تميز أيضاً العمق 10 سم في نسبة الربح إلى التكاليف في أي إتساع ومع أي حالة سواء "خ ر" أو "خ م"، وكانت أعلى نسبة في حالة عدم وجود تضخم (وجود تضخم) هي 6.16 (5.60) للإتساع بين الخطوط 0.9 – 1.2 م والعمق 10 سم بالحالة "خ ر".

يفضل عمق خط التنقيط 10 سم حيث أعطى تميز نسبة الربح على التكاليف سواء في حالة وجود/عدم وجود حاجز في كلا الترتيبين لخطوط التنقيط المفصولة راسياً والمتلازمين. حيث كانت أعلى نسبة هي في حالة عدم وجود تضخم (وجود تضخم) 6.16 (5.60) و المتحصل عليها من الإتساع 0.9 – 1.2 م في حالة وجود حاجز وترتيب خطوط التنقيط المفصولة رأسياً.

أما إذا كان الهدف هو أقل تكلفة سنوية فأن حالة الخطوط المتلازمة والإتساع 0.8 – 1.0 م والعمق 10 سم في حالة عدم وجود عازل كانت أقل تكلفة سنوية وهي في حالة عدم وجود تضخم (وجود تضخم) 2333 (2566) جنية.

ولذا يمكن التوصية في حالة عدم إستخدام الحاجز تحت سطحي بعمق خطوط التنقيط تحت السطحية 10 سم مع حالة الترتيب الخطوط المفصولة رأسياً "خ ر" والإتساع بين الخطوط 0.4 – 0.6 م وذلك للطماطم والبصل.

ومدى إتساع بين الخطوط 0.9 – 1.2 م وعمق خطوط التنقيط 10 سم للخطوط المفصولة رأسياً وذلك في حالة وجود حاجز بولي إثيلين تحت سطحي (عمق الحاجز 40 سم من سطح الأرض) لمحصول الطماطم.

ومدى إتساع بين الخطوط 0.3 – 0.6 م وعمق خطوط التنقيط 25 سم للخطوط المتلازمة وذلك في حالة وجود حاجز بولي إثيلين تحت سطحي (عمق الحاجز 55 سم من سطح الأرض) لمحصول البصل.