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Improving water use efficiency of strawberry under some cultivation systems

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ABSTRACT

This investigation is an attempt to compare between two cultivation systems and the effect of irrigation mode (times and duration) on improving water use efficiency of strawberry. The two systems are; soil-less and soil cultures grown in El-Sheikh Zuwayid Research station, North Sinai, Egypt. Two experiments were conducted in randomized complete blocks design with three replicates. The treatments include two cultivation systems as main plots: A)-soil culture system and irrigation mode as sub-main plots; three daily irrigation times by drip irrigation system there were, i.e., (T_1) 1/4 hour, (T_2) 1/3 hour and (T_3) 1/2 hour with dripper discharge 4L/hour and, B) For soil-less culture system a deep-flow technique (DFT) with intermittent circulation (DFT/IC) as main plot, and sub-main plots as three daily irrigation times duration i.e.; (D_1) 1/4 hour (4 times), (D_2) 1/3 hour (3 times) and (D_3) 1/2 hour (twice) as hydroponics system DFT is a closed system. The results were analyzed statistically. From the experiments, the following results were obtained: Significant differences among all treatments in soil culture, but non significant differences in soil-less culture for fruit yield of strawberry. The magnitude is in the order: $T_2 > T_1 > T_3$ and $D_2 > D_1 > D_3$ for the two trials. Strawberry produced higher fruit yield in soil-less culture than the conventional system. Significant decrease in water consumptive use of strawberry by decreasing irrigation times in the order of $T_1 < T_2 < T_3$ in soil culture system. But in soil-less culture system the water consumptive use value significantly decreased by increasing irrigation duration and decreasing the number of irrigation cycles, in the order of $D_3 < D_2 < D_1$. Significant increase in water use efficiency of strawberry by decreasing irrigation times in the order of $T_1 > T_2 > T_3$ in soil culture system. But in soil-less culture system the WUE value significantly increased by increasing irrigation duration and decreasing the number of irrigation cycles, in the order of $D_3 > D_2 > D_1$. It is suggested to cultivate strawberry plants and irrigate daily with one liter per plant in soil culture and twice at times of half an hour under the conditions of hydroponics system DFT in closed system at open field in El-Sheikh Zuwayid to obtain the highest water use efficiency. From the economic point of view, applying daily irrigation water amount of 1.33 liter per plant in soil culture and at times of 1/3 hour 3 times in soil-less culture leads to the highest investment ratio (IR).

KEYWORDS

Cultivation systems;
Hydroponics;
Soil-less;
Irrigation times;
Irrigation duration;
Strawberry;
Water use efficiency.

INTRODUCTION

The global crisis of fresh water obliges the crop producers to reach to the highest water use efficiency level. Simultaneously the financial crisis obliges them also to select the most economic technique. Actually, this work discusses both thoughts in unique application.

Strawberry is one of the most delicious, nutritious, and refreshing fruits. Basically, it is a fruit plant of temperate regions, but it grows profitably well in tropical and sub-tropical climates[19].

Strawberries have been produced in vertical systems to use the vertical space high density system[6]. Blaine et al.[1] reported that using drip irrigation on row crops and applying small amounts of water slowly and frequently through emitters spaced along polyethylene tape or tubing - is now the main method used in California to irrigate strawberries.

The use of hydroponic systems to optimize water and fertilizer use efficiency is nowadays widely used system. Hydroponics is a way of growing plants without soil and adjusts watering times and intervals to maximize growth and minimize water use. In this regard, solution culture or liquid hydroponics-circulating methods (closed system), Nutrient Film Technique (NFT) and Deep Flow Technique (DFT) are adopted.

Montri and Wattanapreechanon[13] reported that soil-less culture is popular especially for vegetables, especially in areas of poor soil and unreliable water resources. Kirnak et al.[11] stated that shallow root zones and sandy soil types will require frequent watering of a shorter duration, adjusted watering times and intervals which maximize growth and minimize water use. El-Behairy et al.[7] found that using NFT gave earlier yield with higher quality of strawberry.

Kalle and Tapio[10] reported that water consumption of plants varied considerably depending on growth stage, yield potential and environmental factors. The average water consumption is between (1932 – 2730 m^3/fed/year) depending on regions and soils. The volume of irrigation water ranged from 50 to 220 l/plant per growing season. Evenhuis and Alblas[8] showed that crop productivity increased at lower tensiometer values than assumed. Growing strawberries at field capacity (100 hPa) led to an increase in yield of 1.0 t/ha compared to strawberries grown in a field irrigated at (200 hPa). Lydia et al.[12] found that the maximum strawberry yield was attained at (-0.01 MPa) soil water potential.

To use water efficiently and to avoid loss through percolation, frequent irrigation using small amounts of water is necessary. According to Chaves et al.[2] most plants tend to show an increase in water-use efficiency when water deficit is mild.

This investigation is an attempt to clarify the effect of cultivation systems, irrigation mode (times and duration) to improve water use efficiency of strawberry in two experiments on soil-less and soil culture located at El-Sheikh Zuwayid Research station, North Sinai, Egypt.

MATERIALS AND METHODS

This investigation is an attempt to clarify the effect of cultivation systems, irrigation mode (times and duration) to improve water use efficiency of strawberry in two experiments conducted on soil-less system and conventional soil with drip irrigation system. The experiments were carried out during the winter season of 2008/2009 in El-Sheikh Zuwayid Research station, North Sinai, Egypt. The experimental field has an altitude of about 15 meter above sea level and located at 31°.08'N and 34°.01'E. Figure 1 Shows the average of meteorological data of North Sinai during 12 years (1996 - 2007). In general, the northeastern part of Sinai Peninsula is characterized by the Mediterranean climate, having dry hot summer and relatively cold winter.

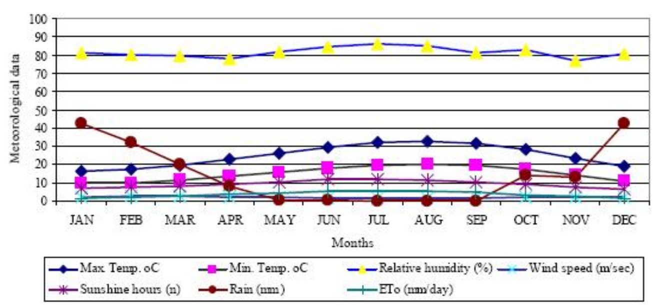

Figure 1 : Meteorological data of North Sinai, average of 12 years (1996-2007)

The study was conducted in a randomized complete blocks design with three replicates. The treatments include two cultivation systems as main plots: A)-soil culture system and irrigation mode as sub-main plots; three daily irrigation times by drip irrigation system there were, i.e., (T_1) 1/4 hour, (T_2) 1/3 hour and (T_3) 1/2 hour with dripper discharge 4L/hour and, B) For soil-less culture system a deep-flow technique (DFT) with intermittent circulation (DFT/IC) as main plot, and sub-main plots as three daily irrigation times duration i.e.; (D_1) 1/4 hour (4 times), (D_2) 1/3 hour (3 times) and (D_3) 1/2 hour (twice). Nursery was planted on 18th September 2008 for soil-less and soil cultures. In 16th October 2008 strawberry plants were transplanted in both soil-less and soil culture systems, after a nursery period of 28 days.

Soil-less trial

Deep flow technique (DFT) – Pipe system

Most commercial hydroponic systems direct a continuous flow of nutrient solution over the plant roots as described by Takeda[21] and Olympios[14]. The system content of 75 pattern/fed, each pattern content of 4 units (4x13 m), each single unit 5 PVC pipes with 12 m long, each pipe content of 46 plants (69000 thinned). System cost is about 60000 LE for 5 years duration that could include ≈ 10 - 15 growth seasons. TABLE 1 shows the nutrient solution contents.

All treatments received the recommended doses of mineral fertilization NPK through irrigation fresh water, i.e., fertigation[4], (2 kg), NPK as (nitrate, phosphoric acid P_2O_5, potassium) every one week. The micronutrients; zinc, copper, (200 g) iron and (100 g) manganese chelates beside (200 g) potassium, were applied foliarlly every two weeks. The solution volume was measured twice a week and adjusted to a constant volume by adding tap water (TABLE 2), Rainwater and Thatcher[16]. Irrigation water amounts are shown in TABLE 3.

Cumulative water consumptive use was recorded using water budget method as described by Cooper[3].

TABLE 1 : Chemicals needed to prepare 1000 liters of nutrient solution
(Albert's mixture, locally available in the market)

Nutrient chemicals	Weight in grams
Multi-K (Potassium nitrate)	38.0
Refined grade calcium nitrate	952.0
Magnesium sulphate	308.0
EDTA iron	8.0
Zinc sulphate	0.15
Boric acid	0.20
Manganese sulphate	1.15
Copper sulphate	0.10
Mono potassium phosphate	269.0
Potassium sulphate	423.0
Ammonium molybdate	0.03

TABLE 2 : Chemical analysis of tap water used for hydroponics irrigation

P^H	E.C dS/m	S.A.R	Soluble cations me/l				Soluble anions me/l				Class
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	$SO_4^{=}$	Cl^{-}	
7.0	0.94	1.74	3.42	1.82	2.82	1.32	0.00	4.25	1.17	3.96	C_3 S_1

pH = soil reaction E.C. = electrical conductivityd S/m = deci Siemens per metre S.A.R = Sodium adsorption ratio

TABLE 3 : Computed irrigation water amounts added to cultivation soil-less system (DFT) (m^3/fed)

Daily irrigation times duration	September (Nursery)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Season
(D_1) 1/4 hour (4 times)	4.67	25.81	51.96	85.22	143.08	126.55	66.72	504.01
(D_2) 1/3 hour (3 times)	4.67	20.65	49.88	81.81	137.36	121.49	63.90	479.76
(D_3) 1/2 hour (twice)	4.67	17.21	41.57	68.17	114.47	101.24	52.63	399.96

Field trial

The soil physical and chemical characteristics of the studied site were determined according to Richards[18] TABLES (4a & b). The soil is sandy and saline, EC 1.72 dS/m and pH 7.4.

The chemical analysis of irrigation water was carried out using the standard methods of Rainwater and Thatcher[16]. Saline ground water was used for irrigation viz a drip system. TABLE 5 revealed that, this water attains high salinity (4.0 dS/m), medium sodium, i.e., C_4 S_2 water; having pH 7.2 (neutral). Drip irrigation system having 4 liter/hour GR dripper was used.

Strawberry seedlings were planted in 16th October 2008 in 15-m long rows, 18 rows spaced 1-m apart. Plants are aparted 1 m between the plant rows, and 30 cm between plants in the row, 14,000 plants were grown per feddan. A single emitter was placed at the base of each plant. Organic manure was added to soil by about 20 m^3/fed before planting. All treatments received the recommended doses of mineral fertilization NPK[4], which include about 100 kg/fed superphosphate (15.5 % P_2O_5) added before planting, 100 kg/fed ammonium nitrate (33.5 % N) and about 96 kg/fed potassium sulphate (48 % K_2O). These mineral fertilizers were added with specific quantities according to the growth stages of plants. Fertilization was conducted through irrigation water, i.e. fertigation. Micronutrients, i.e., zinc, copper, iron and manganese chelates were applied as foliar application every two weeks.

TABLE (4a) : Some physical properties of the soils selected for experimental work

Soil depth (cm)	Particle size distribution (%)				Texture class	Particle density (g/cm^3)	Bulk density (g/cm^3)	Total porosity (%)	Organic matter (%)	Moisture content (%)		Available soil water/layer		Infiltration rate	
	Coarse sand	Fine sand	Silt	Clay						Field capacity	Wilting point	(%)	(mm)	(cm/hr)	Class
0-50	7.25	87.81	2.69	2.25	Sandy	2.55	1.45	43.14	0.24	10.12	2.87	7.25	52.56	16.4	Very rapid

TABLE (4b) : Some chemical and physico-chemical properties of the soils selected for experimental work

Soil depth (cm)	$CaCO_3$ (%)	pH soil paste	ECe (dSm^{-1})	Soluble cations (me/l)				Soluble anions (me/l)				CEC (me/100g soil)	Exchangeable cations (me/100g soil)			
				Ca^{++}	Mg^{++}	Na^+	K^+	$CO_3^=$	HCO_3^-	$SO_4^=$	Cl^-		Ca^{++}	Mg^{++}	Na^+	K^+
0-50	5.33	7.4	1.72	8.31	1.39	1.64	5.85	_	4.86	6.09	6.24	2.71	1.48	0.36	0.67	0.20

TABLE 5 : Chemical analysis of the well irrigation water of North Sinai research station

P^H	E.C dS/m	S.A.R	Soluble cations me/l				Soluble anions me/l				Water class
			Ca^{++}	Mg^{++}	Na^+	K^+	$CO_3^=$	HCO_3^-	$SO_4^=$	Cl^-	
7.2	4.00	4.80	10.51	10.75	15.64	3.10	0.00	11.42	12.14	16.44	C_4 S_2

Plants were covered with white plastic sheets and used as mulch from mid December up to late February for winter protection. After that a thin layer of the plastic sheet still used as mulch in the row during spring (late February), where after this period the climate condition became warm.

Strawberry plants were managed using the recommendations outlined in the *Strawberry Production Guide*[15]. The amounts of applied nursery irrigation are calculated as; = ((8 liter/m^2/day) x (nursery area for 84000 plant about 100 m^2) x (reduction factor 0.25) x (nursery irrigation period 28 days)) /1000 = 5.60 m^3/feddan. So, for nursery period all plants get 4.67 m^3/feddan in soil-less and 0.93 m^3/feddan in soil culture. The amounts of applied irrigation water in drip irrigation system are shown in TABLE 6.

TABLE 6 : Computed irrigation water amounts added (m^3/fed).

Daily irrigation times	September (Nursery)	October	November	December	January	February	March	Season
(T_1) 1/4 hour/plant	0.93	210.00	420.00	434.00	434.00	406.00	224.00	2128.93
(T_2) 1/3 hour/plant	0.93	279.30	558.60	577.22	577.22	539.98	297.92	2831.17
(T_3) 1/2 hour/plant	0.93	420.00	840.00	868.00	868.00	812.00	448.00	4256.93

To determine the actual water consumption, soil moisture tension was measured by tensiometer, while moisture content was determined by weighing method and hence the actual evapotranspiration was calculated according to Doorenbos and Pruitt[5].

Five collections in each culture system were get to determine fruit strawberry yield from mid February up to 16th March 2009 season, after 180 days from sowing seeds, so, strawberry fruit yield was determined and recorded. The water use efficiency was calculated by dividing the fruit yield by the amount of seasonal actual evapotranspiration[9]. The investment Ratio (IR) = Output LE / Input LE = costs[17]. Data were subjected to the analysis of variance of the split split plot design (ANOVA and L.S.D.) according to the method described by Snedecor and Cochran[20].

RESULTS AND DISCUSSION

Strawberry yield

Data in TABLE 7 present the fruit yield under the experimental conditions. From the table it can be conclude the following:

1- The total fruit yield as g/plant for the 5 collection is generally higher in soil culture than in soil-less condition by 50 %. This could be render to the competition among plants in soil-less experiments which is higher than that in soil culture. Obviously, the area for root extensions is more confined in the former than in the latter; also the soil material adjusts itself to provide suitable conditions for plant growth.

TABLE 7 : Fruit yield of strawberry grown in North Sinai region

Treatments		Harvest fruit yield (g/plant)					Total fruit yield (g/plant)	Total fruit yield (ton/fed)
Cultivation systems	Daily irrigation times	1st harvest	2nd harvest	3rd harvest	4th harvest	5th harvest		
Soil	(T_1) 1/4 hour	75	85	92	94	90	436	6.104 b
	(T_2) 1/3 hour	87	96	113	120	117	533	7.462 a
	(T_3) 1/2 hour	70	82	85	90	80	407	5.698 b
	Average	77	88	97	101	96	459	6.421
Soil-less (DFT)	(D_1) 1/4 hour, 4 times	59	62	63	64	63	311	21.364 a
	(D_2) 1/3 hour, 3 times	61	64	65	63	65	318	21.844 a
	(D_3) 1/2 hour, 2 times	53	58	60	59	61	291	19.990 a
	Average	58	61	63	62	63	307	21.066

a, b, c letters indicated significant differences among treatments. L.S.D. 0.05 = 0.79* & 2.15^{ns} for soil and soil-less cultures, respectively.

2- The obvious high Figure of yield as ton/fed is render to the number of plants under each experiment as it reach to about 5 folds in soil-less than soil culture experiment.

3- Regardless of applied treatments, the harvested fruit yield tends to increase progressively to reach its maximum in the 4th harvest of plants grown in soil culture. On the other hand, fruit yield of plants grown in soil-less culture displayed a slight increase in 2nd Harvest relative to the 1st one almost constant from the 3rd to the 5th collection.

4- Considering the effect of irrigation mode, the data indicate that the highest fruit yield corresponds to T_2 (1/3 hour) followed by T_1 (¼ h/plant) while T_3 (½ h/plant) led to the least fruit yield in plants grown in soil culture. Likewise, slightly higher fruit yield corresponds to D_2 (1/3 h, 3 times) followed by D_1 (¼ h, 4 times) and the least fruit yield at D_3 (½ h, 2 times) in plants grown in soil-less culture. Data also reveal that the highest yields was commonly associated with applying irrigation water amount about (1.33) liter/plant/day in soil culture and duration 20 minute 3 times per day in soil-less culture.

Statistical analysis shows significant differences among all treatments for soil culture, but non significant differences in soil-less culture among all treatments for fruit yield of strawberry.

Harmony results were obtained by Lydia et al.[12]; Evenhuis and Alblas[8]; El-Behairy et al.[7]; Kirnak et al.[11]; Montri and Wattanapreechanon[13] and Kalle and Tapio[10].

Water consumption

One of the advantages of soil-less cultivation is that it minimizes the evaporated water from soil, so mostly the water consumption is relative to the transpired portion of water.

TABLE 8 shows water consumption values for the whole experiment.

From the table it can be note the following:

a- Water consumption of strawberry plants in soil culture was greatly higher than in soil-less culture.

b- The table also reveals that the lowest values were commonly associated with applying irrigation water amount of about (1.0) liter/plant/day in soil culture and duration 30 minute twice per day in soil-less culture.

TABLE 8 : Water consumptive use (m^3/fed) of strawberry grown in North Sinai.

Treatments		Water consumptive use (m^3/fed)							
Cultivation systems	Daily irrigation times	Sep. (Nursery)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Season
	(T_1) 1/4 hour	0.93	137.68	304.83	318.15	314.11	331.88	161.58	1569.16 c
Soil	(T_2) 1/3 hour	0.93	172.09	398.36	409.05	392.64	414.85	201.04	1988.96 b
	(T_3) 1/2 hour	0.93	240.93	581.96	599.94	578.25	606.05	296.87	2904.93 a
	Average	0.93	183.57	428.38	442.38	428.33	450.93	219.83	2154.35
	(D_1) 1/4 hour, 4 times	4.67	25.81	51.96	85.22	143.08	126.55	66.72	504.01 a
Soil-less (DFT)	(D_2) 1/3 hour, 3 times	4.67	20.65	49.88	81.81	137.36	121.49	63.90	479.76 a
	(D_3) 1/2 hour, 2 times	4.67	17.21	41.57	68.17	114.47	101.24	52.63	399.96 b
	Average	4.67	21.22	47.80	78.40	131.64	116.43	61.08	461.24

a, b, c letters indicated significant differences among treatments. L.S.D. 0.05 = 27.01* & 45.08* for soil and soil-less cultures, respectively.

c- The amount of consumed water significantly correlated with irrigation amount of water in soil culture. Decreases in water consumptive use of strawberry by decreasing irrigation times, in the order: $T_1 < T_2 < T_3$.

d- In soil-less experiment it decreased significantly in the direction of $D_3 < D_2 < D_1$ which could explain by increasing the times of root exposure to water application.

e- The mode of water consumption along the growth period is almost similar in both cultivation systems being increased gradually along the growth period then declined with harvest.

With reference to water saving, certain soil-less systems, for instance the close recirculated ones, undoubtedly economize water because drainage and evaporation from the surface is eliminated by the design and operational scheme of the systems (DFT, “closed” systems, sub-irrigated soil-less culture). In addition, with soil-less cultures more accurate control over the supply of water is practiced. Regarding soil culture, it is noticed that minimum water amount was sufficient to kept soil wet, so, higher consumptive use in higher irrigation treatments are mainly rendered to increasing evaporation rates from the soil matrix. Regarding soil culture, it is noticed that minimum water amount was sufficient to kept soil wet, so, higher consumptive use in higher irrigation treatments are mainly rendered to increasing evaporation rates from the soil matrix. The results coincide well with those obtained by El-Behairy et al.[7]; Kirnak et al.[11]; and Kalle and Tapio[10].

Water use efficiency

This expression deals with two meanings: a- How much water needs for producing one unit of any crop yield (especially the economic parts) and b- How much crop yield could be produced from the unit of water. Both meanings are tackled, in fact, with the two global crises of water and finance. Obviously, we must continuously search for the best ways to improve the WUE. TABLE 9 shows that water use efficiency of strawberry plants in soil culture was greatly lower than in soil-less culture. This result may be attributed to the low water consumption by recycling water in closed system. Data also reveal the highest values were commonly associated with applying irrigation water amount about (1.0) liter/plant/day in soil culture and duration of 30 minute twice per day in soil-less culture. Statistical analysis show significant differences among all treatments for soil and soil-less culture for water use efficiency of strawberry. Significant increase in water use efficiency of strawberry by decreasing irrigation times, in the order: $T_1 > T_2 > T_3$ in soil culture, but increased by increasing irrigation times duration, in the order: $D_3 >$

$D_2 > D_1$ in soil-less culture.

TABLE 9 show the WUE values calculated for the two meanings. From the data it can be note the following:

1- Using one m^3 unit of water we can produce generally 15 times from soil-less system referring to soil culture.
2- The maximum WUE value was obtained with least irrigation water in both soil and soil-less culture systems.
3- To produce one unit crop yield (as ton) it seems more benefit to use least irrigation water under the two irrigation systems. However, under this condition still soil-less system use about 1/13 times of water referring to soil culture.

TABLE 9 : Water use efficiency (kg/m^3) of strawberry grown in North Sinai

Treatments		Strawberry				
Cultivation systems	Daily irrigation time	Fruit yield (Kg/fed)	ETa (m^3/fed)	WUE (Kg/m^3)	Modified WUE (g/liter)	WUE (m^3/ton)
	(T_1) 1/4 hour	6104	1569	3.89 a	3.89	257.22
Soil	(T_2) 1/3 hour	7462	1989	3.75 a	3.75	266.63
	(T_3) 1/2 hour	5698	2905	1.96 b	1.96	510.09
	Average	6421	2154	3.20	3.20	344.65
	(D_1) 1/4 hour, 4 times	21364	504	42.39 b	8.59	23.73
Soil-less (DFT)	(D_2) 1/3 hour, 3 times	21844	480	45.53 ab	9.22	22.10
	(D_3) 1/2 hour, 2 times	19990	400	49.98 a	10.12	20.13
	Average	21066	461	45.97	9.31	21.99

a, b, c letters indicated significant differences among treatments. L.S.D. 0.05 = 0.65* & 5.06* for soil and soil-less cultures, respectively.

Actually, the results are important from several points of view:

a- For the areas which suffer from severe shortage of water to produce the urgent food needs.
b- For maximizing the productivity of both natural resources of soil and water as well.
c- In planning the forms under the same conditions to the least requirement of input to produce the maximum crop yields.
d- When modifying the data on the same plant population base of soil culture system (14000 plant/fed) the data of soil-less system overcome the soil culture by about 3 times.

When applying proper treatments and good managing of soil regimes, it is expected that these practices activate both water and nutrient consumptions by roots of plants which, increased crop yield, thus increased W.U.E. This increase in W.U.E. is due to; shallow root zones of strawberry grown in sandy soil require frequent watering of a shorter duration, the decrease of actual evapotranspiration (T_1&D_3) at low amount of irrigation water, (T_1) thus adjusting watering times and intervals to maximize growth, minimize water use and correspondent high yield. So, it is suggested that these practices activate both water and nutrient consumptions by plant roots which increased crop yield, thus increased W.U.E. These findings are in harmony with Evenhuis and Alblas[8]; El-Behairy et al.[7] and Chaves et al.[2].

Economical assessment

Practically, the economical evaluation of the experimental findings is of major concern since the net return of such treatments could encourage the farmer to use the technique or not. In this respect, the investment ratio is computed as a guide where the investment ratio (IR) = Output LE / Input LE. The obtained values of investment ratio (IR) are illustrated in TABLE 10. From the table, it is clear that:

1- It is obvious that all data overcome the national reported IR by different rates being higher in soil culture than soil-less system due to high expenses of latter than the former.
2- The highest IR values for both systems are corresponded to the medium water amount; i.e. T_2 and D_2.
3- The results provide many options for the producers depending on their financial situation and water source satisfaction.

Furthermore, water culture and sub-irrigated substrate systems save much labor in the time consuming task of checking and cleaning irrigation nozzles.

This trend is in harmony with U.S.D.A[22] and Chaves et al.[2].

TABLE 10 : Investment ratio (IR) of strawberry grown in North Sinai region

Economical items	Agriculture systems	Soil			Soil-less (DFT)		
		Daily irrigation times			Daily irrigation times duration		
	Field practices	(T_1) 1/4 hour	(T_2) 1/3 hour	(T_3) 1/2 hour	(D_1) 1/4 hour (4 times)	(D_2) 1/3 hour (3 times)	(D_3) 1/2 hour (2 times)
List of inputs, LE/fed	Land preparation, LE/fed	100	100	100	100	100	100
	Seeds, LE/fed	200	200	200	1000	1000	1000
	Cultivation, LE/fed	100	100	100	250	250	250
	Irrigation, LE/fed	533	709	1065	126	120	100
	Irrig. systems costs, LE/fed	300	300	300	6000	6000	6000
	Mineral fertilizer, LE/fed	150	150	150	150	150	150
	Organic fertilizer & Nutrient solutions, LE/fed	300	300	300	7350	7350	7350
	Fert. labors costs, LE/fed	100	100	100	100	100	100
	Pest control, LE/fed	100	100	100	100	100	100
	Weed control, LE/fed	100	100	100	100	100	100
	Machines, LE/fed	100	100	100	100	100	100
	Fuel, LE/fed	100	100	100	250	250	250
	Harvesting, LE/fed	100	100	100	500	500	500
	Crop transport, LE/fed	100	100	100	100	100	100
	Rent (on season), LE/fed	300	300	300	300	300	300
	Total inputs, LE/fed	2683	2859	3215	16526	16520	16500
List of outputs	Strawberry yield, kg/fed	6104	7462	5698	21364	21844	19990
	Price, LE/kg	1.50	1.50	1.50	1.50	1.50	1.50
	Total prices, LE/fed	9156	11193	8547	32045	32767	29984
	Net income, LE/fed	6473	8334	5332	15519	16247	13485
Investment ratio, LE		3.41	3.92	2.66	1.94	1.98	1.82

The national reported IR value of 1.25 LE

CONCLUSIONS

From the aforementioned results it is clear that the study provide many promised option for producing strawberry under similar conditions to the site of experiments. However, the selected application from the resulted data will depend on the land and water resources in the location and the financial situation of the producer as well. Consequently, when the water source is very limited it is urgent to select the soil-less system with any of water application rate as all of them get beneficial return. On the other hand, when the financial resource is limited it is beneficial to use the soil culture system with minimum water application to get highest WUE or medium rate to get the highest IR value.

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