DEVELOPMENT OF WATER CULTURE SYSTEM DEPENDING ON RENEWABLE ENERGY TO SUIT REMOTE AREAS

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ABSTRACT

This study aims to evaluate two closed solar pumping systems with hydroponic (NFT) units using (large and small scale-models with same mechanism, and were planted with cucumber (Cucumis sativus L, Beta Alpha var.) and mint (Mentha viridis, Mentha spicata var. ciliate) respectively to present a suitable solution for electricity problem in the remote areas, as well as aims to introduce a water saving technique (hydroponic), to cope with water scarcity problem in arid areas.

The effect of daily solar radiation and motor speed (rpm) on the water flow rate of the two systems were evaluated, the results indicated that as daily solar radiation increased, the motor speed (rpm) increased, and consequently the flow rate increased for the two pumping systems, but the increasing of the flow rate for DC motor pump was more effective.

The average leaf area was determined at the end of the culture season for cucumber and mint. The results indicated that the water consumption for one plant of cucumber and mint were 46.7 and 9.4 litters respectively at the end of the season, and (WUE) for one plant of cucumber and mint were 53.5 and 42.328 g/liter respectively, also, the average leaf area for one plant of cucumber and mint were 196.08 and 2.7 cm^2 respectively.

Key words: *Solar energy – photovoltaic cells – AC motor – DC motor – Hydroponic – NFT culture – Cucumber – Mint.*

1-INTRODUCTION

By 2050 a 70 percent increase in current food production will be necessary to meet the expanding demand for food, primarily through yield increases. The use of fossil fuels by agriculture has made a significant contribution to feeding the world over the last few decades.

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Energy from fossil fuels has increased farm mechanization, boosted fertilizer production and improved food processing and transportation. However, if an inexpensive supply of fossil fuels becomes unavailable in the future, options for increasing food productivity may become severely limited.

Electricity generation from solar thermal system is based on the same methods of energy conversion and components used in conventional thermal power plants to produce electricity, with the replacement of fuel used by the thermal energy resulting from the concentration of solar radiation at high temperature (400°C – 1500°C). Such systems can be used as central power plants and connected to grid. Also, some of these systems can be used as individual units in remote areas and limited capacity.

The total installed capacity of PV systems in Egypt is around 10 MW for lighting, water pumping, wireless communications, cooling and commercial advertisements on highways. (**NREA, 2010)**.

Due to reported studies about the advantages and disadvantages of the photovoltaic cells, it was necessary in this study to shed light on them, to avoid mistakes, which reduce the efficiency of these systems. Experiments were simple with less possibility. In this study, large and small- scale models were available, to activate the previous concept in remote areas, to encourage desert invasion, and create new investment projects. The developing countries of the world, especially developing with big population, are confronted with a multitude of complex problems, involving: population growth, economies, energy, and development. Unfortunately, all these problems are closely interrelated and they have been seriously aggravated by the strong fluctuations in the oil prices. Photovoltaic (PV) generation represents one of the methods of converting the sunlight directly into electricity and is applicable to most geographical regions.

Egypt has been listed among the ten countries that are threatened by want of water by the year 2025 due to the rapidly increasing population. About 97% of Egypt's water resources are from the river Nile. The rest is from winter rain and non-renewable ground water aquifers **(Abdel-Shafy and Aly, 2002).**

On the other hand the majority of salt-affected soils in Egypt are located in the Northern Nile Delta. In About 900,000 ha of Egypt’s agricultural lands are suffering from salinity build-up problem. Across Egypt's agricultural land profile, salt-affected soils represent about 60, 20 and 25% in North Delta, South Delta and Upper Egypt regions respectively, **(Dinar *et al.* 2012).**

In some coastal areas the extraction of groundwater has proceeded to the point where intrusion of saline seawater into aquifers has degraded the quality of these resources. Continued irrigation with such low quality groundwater has contributed to the expansion of land salinization. Saline soil distribution is closely related to environmental factors such as climatic, geological, geochemical and hydrological conditions.

This study was conducted in the new valley, which is located in the south-west of Egypt**,** Western Sahara, also, aims to benefit from solar radiation in the New Valley province, El-Dakhla, Mut city, as well as to introduce a new method of agriculture (Hydroponic), which saves irrigation water. The farming methods there depend on intensive irrigation and waste huge amounts of water. It is hoped to open new horizons for planting more plants, such as; medicinal and aromatic plants, fodder and vegetables to achieve self-sufficiency for the province from agricultural production.

Hydroponics is often defined as "the cultivation of plants in water". Hydroponics is however a technique for growing plants without using soil. Utilizing this technology, the roots absorb a balanced nutrient solution dissolved in water that meets all the plants developmental requirements.

Advantages of hydroponics:

1- The possibility of obtaining more products in less time than using traditional agriculture.
2- The possibility of growing plants more densely.
3- Possibility of growing the same plant species repeatedly because there is no soil depletion.
4- Plants have a balanced supply of air water and nutrients.
5- More product/surface unit is obtained.
6- Cleaner and fresher products can be reaped.
7- Production can be timed more effectively to satisfy market demand.
8- Healthier products can be produced.
9- Products are more resistant to diseases.
10- Natural or Biological control can be employed.

11- Soil borne pests (fungi) and diseases can be eliminated.
12- Troublesome weeds and stray seedlings which the result in the need for herbicides use and increase labor cost, can also be eliminated.
13- Reduction of health risks associated with pest management and soil care.
14- Reduced turnaround time between planting as no soil preparation is required.
15- Stable and significantly increased yields and shorter crop maturation cycle.
16- Can be utilized by families with small or no yard space.
17- When water is used as the substrate:
  a. No soil is needed.
  b. The water stays in the system and can be reused - thus, lower water costs.
  c. It is possible to control the nutrition levels in their entirety - thus, lower nutrition costs.
  d. No nutrition pollution is released into the environment because of the controlled system.
18. Pests and disease are easier to get rid of because of container mobility.

So, the following objectives of this work are:

1- To carry out hydroponic Nutrient-Film Technique (NFT) system depending on flow of the nutrient solution from upper tank (feeding tank) under gravity via culture pipes to lower tank (collecting tank). The solution is re-circulated to the upper tank again by solar motor-pump, and the feeding tank water consumption is compensated by refilling it manually.
2- Cucumber (*Cucumis sativus L, Beta Alpha var.*) and mint (*Mentha viridis, Mentha spicata var. ciliate*) were planted in (NFT) system. Water consumption, water use efficiency (WUE), average leaf area cucumber yield and whole mint plants were determined.
3- Cost analysis.

2-REVIEW OF LITERATURE

Ghoneim(2006) presented the results of performance of optimization of a photovoltaic powered water pumping system in the Kuwait climate. It affirmed that the water requirement increases during hot weather periods when the solar radiation intensity is high and the output of the solar array is at its maximum. On the other hand, the water requirement decreases when the weather is cool and the sunlight is less intense. **Tawfiq *et al.* (2007)** installed a closed renewable energy system to pace with the sustainable development in remote areas. The system uses saline ground water lifted by a windmill, distilled by solar still unit and added with nutrient solution. The nutrient solution is recycled by the windmill to be used by plants with Nutrient Film Technique (NFT).Squash and mint were planted. The experimental work was carried out at the Northern Coast where the results indicated that, increasing in discharge rate by 100, 250, 150% at 2.5, 5, 7, m/s wind speed, respectively as compared with the standard condition. The average daily productively of solar still in summer was 3.1 $l/m^2/day$. The water use efficiency for squash and mint was about 55 and 19 g/l as fresh weight respectively. Profitability of the system was acceptable and may be utilized directly in remote areas, but it needs advanced management. **Vick and Clark (2009)** tested field many different types of solar powered water pumping systems for several years. So, several steps are given to select a solar-PV water pumping system. The steps for selection of stand-alone water pumping system were: deciding whether a wind or solar water pumping system would be best, determining the type of PV module, how controller can affect the decision, selecting pump type (diaphragm, piston, helical, or centrifugal), and analyzing the monthly water demand requirement. Three case studies are also included to demonstrate how to determine PV array size, motor/pump rated power, and type of pump. **Hegazy (2010)** modified a locally assembled solar-powered irrigation system. A direct-coupled photovoltaic pumping system has been assembled and installed in the Egyptian Desert Institute in Inshas, the system showed trustworthy response to the PV generator output power, demonstrated in DC motor RPM and consequently water delivered. **Grewal *et al.* (2011)** investigate the opportunities in recycling drainage water to increase water and nutrient-use efficiency of hydroponic greenhouses and reduce the environmental impact of the drainage water discharge. Results indicated that a total of 4.15 ML/ha of irrigation water was applied during the 13 weeks crop growing period of which 2.56 ML/ha was drained off and 1.59 ML/ha was used to meet the crop evapotranspiration demand. They showed that the recycling of the drainage water resulted in a 33%

reduction in potable water used for irrigation in cucumber production. The drainage water contained 59% applied N, 25% applied P and 55% applied K and illustrated the potential for nutrient recovery and production cost savings through the reuse of drainage water. This case study demonstrates that some relatively simple changes in irrigation practices within green- house systems to recycle drainage water can considerably improve sustainability of low-cost hydroponic greenhouses and help minimize the environmental footprint of the greenhouse industry. **Sopian, *et al.* (2011)** described several strategies for enhancing of widespread application of renewable energy technology. The strategies include establishing education and capacity building programs, creating renewable energy market and financing mechanism, improving appropriate energy policies and establishing database and international collaboration to promote renewable energy technologies. **Hanif, *et al.* (2012)** conducted an experiment on PV (Photovoltaic) solar panels towards achieving maximum power output. The power output of PV solar panels is examined with different tilt angles (0°, 20°, 35°, 50° and 90°) and different temperatures (15°C to 45°C) of the PV solar panels. The PV solar panels showed maximum power output at a tilt angle of 35° and low temperature of 15°C. Also PV solar panels must be installed at a place where they receive more air currents so that the temperature remains lower and the output remains high**. Senol (2012)** examined a water pumping system with mobile PV power station and studied the technical and economical feasibility of photovoltaic pumping of water in Turkey. Here, he has focused on small and medium-size mobile applications using energy and water- conserving forms of drip irrigation to apple orchard on up to 0.5ha of land in E˘girdir District. Life cycle cost (LCC) method has been applied to determine the economic life of the PV modules, and the diesel pumping in Turkey taken as 25 years.

A power station of the drip irrigation system equipped with PVWP is a mobile system. The mobile system consists of photovoltaic modules and a control unit. Also, he said that the mobile system has more advantages than the fixed system. For instance, it can be used at different irrigation areas in the same irrigation period for individual application. When irrigation is done in an irrigation zone, it can be transferred to another irrigation zone. It can be rented out to other farmers. Also, two or more farmers can use this system in the same irrigation period**. NREA, 2012** said that Egypt has great potential in utilizing solar energy to generate energy products and electricity. However, solar energy is still abandoned in Egypt due to its high costs. In 2012, electricity production from renewable energy sources reached 14,855 Gwh, which is a share of 9.04% of the total electricity production. While 13,358 Gwh (8.13%) were produced by hydropower installations, wind power contributed another 1,260 Gwh (0.77%) and solar PV 237 Gwh (0.14). Solar energy use is still its infancy, with only 15 MW of solar PV installed capacity so far. Additionally, there is one solar thermal project, an integrated solar combined-cycle power plant. Here, the solar power partially replaces fossil fuel. **Alazarda *et al.* 2015** said that semi-arid and arid areas cover one third of the continents and are home to more than 20% of the world population. In these regions, evaporation implies a complete loss of water resources at the basin scale. For both scientific and social reasons, a reliable estimate of loss due to evaporation is thus needed for improved management of water resources

3-MATERIALS AND METHODS

Mechanism for two systems:

Experiments were conducted at Mut city, El-Dakhla, New Valley, Egypt. Two solar systems were installed (large and small-scales) with the same components. The large system was set out during October to December (2013), while the small one was set during February to April (2014). The large system was grown with cucumber, and the small one was planted with mint.

The two proposed solar pumping systems consisted of three units: solar generating, pumping and hydroponic units. The solar unit generates electricity from irradiation. As a result, the motor pump lifts Hogland solution from the ground tank to the upper one. The upper tank (feeding tank) is filled manually with water, and nutrient solution was added at the required rates, then the solution flows from this tank under the influence of gravity to culture pipes (each one has four inches, diameter), and from it to the ground tank (collecting tank), which connected to the solar pump. The solar pump circulates the solution into the upper tank again. The upper tank compensates the consumed solution as a result of water consumption and evapotranspiration of plants by manual refilling.

Fig.(1):System including solar pump and hydroponic unit.

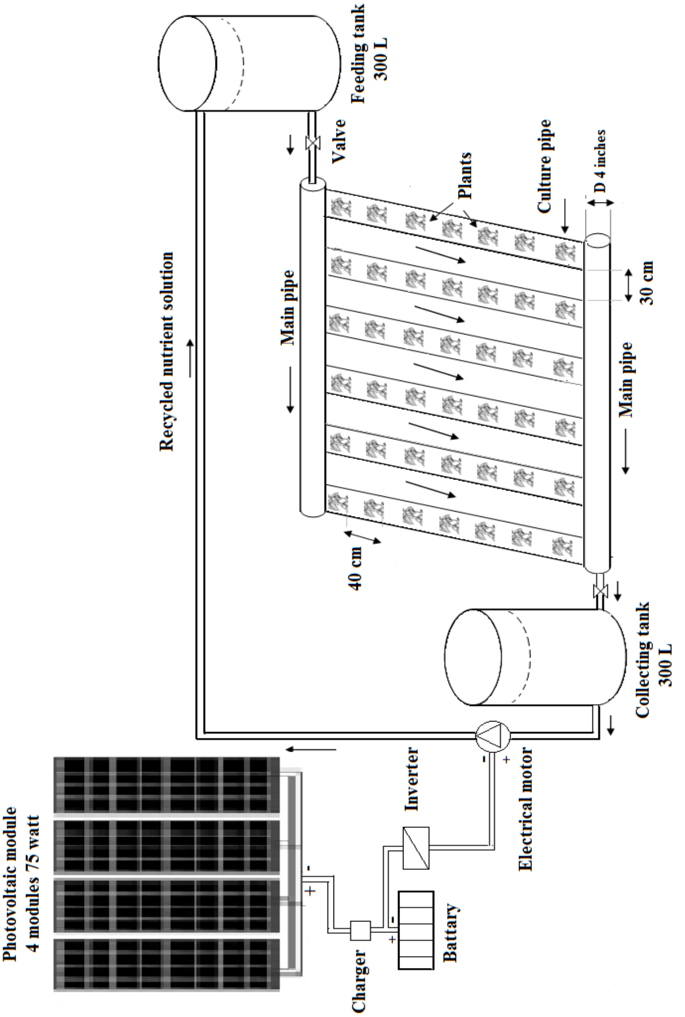


Fig.(2): System including solar pump and hydroponic unit.

Used Materials:

Two solar pumping systems were installed with the same mechanism at The New Valley area, one of these two systems is large scale-model (from October to December 2013), and another one is small scale- model (from November to April 2014). So, the components for two systems are:

a) The large-scale model (from October to December 2013):

Solar system components:

Photovoltaic cells (4 modules, Siemens Showa Solar, polycrystalline, 75 Watt, V = 12 V, I = 4.4 Amps, Dimensions 53cm*120cm), charge controller (12/24V-220V), inverter (12/24V, 50A load, 50A charge current), battery (12 volts 100 Amp.h) as shown in fig. (3).

Fig. (3) PV (Siemens Showa Solar) modules.

Pump components:

A centrifugal pump with (AC) motor (375 W, 2.4 m^3/hr, 1500 rpm), valves, connections (1 inch, let and outlet diameter), as shown in fig. (4) which refers to the motor pump with its inlet and outlet water connections (one inch, diameter).

Fig. (4) Pumping unit including (AC) motor pump.

Hydroponic components:

Two main PVC pipes (2m length, 4 inches diameter), one of two pipes is the inlet water pipe, and the another one is the outlet water, six PVC pipes (3m length, 4 inches diameter), two tanks (each one 300 liter), Hogland solution, cucumber seedlings (15 days age) were planted in this scale.

b) The small-scale model(from February to April 2014):

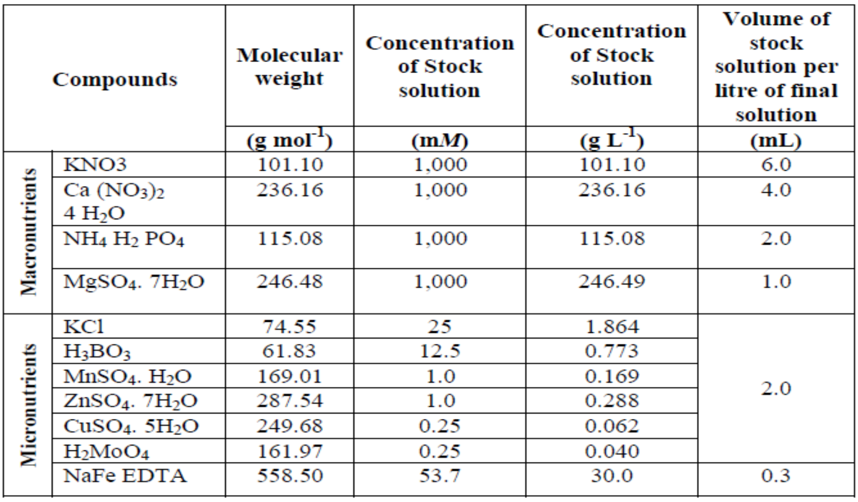
Solar module (which the same modules characteristics for last scale) , DC motor (pumping unit) 30 W, 22 rpm, Q_{max}4 liter/min, H_{max}2.5 m, 12 V, and one PVC pipe (3m length, 4 inches diameter), two tanks (each one is 25liter), Hogland solution, mint seedlings were planted in this scale, as shown in fig. (5).

Fig. (5) Small (DC) motor pump.

Hogland solution:

Hogland solution was used in the two systems, this solution was prepared in Soil Science Department, Faculty of Agriculture – Ain Shams University, and its components are as shown in table (1):

Table (1): Hogland solution components **(Stamps, 2007).**



Compounds		Molecular weight	Concentration of Stock solution	Concentration of Stock solution	Volume of stock solution per litre of final solution
		(g mol^{-1})	(m*M*)	(g L^{-1})	(mL)
Macronutrients	KNO3	101.10	1,000	101.10	6.0
	Ca $(NO_3)_2$ 4 H_2O	236.16	1,000	236.16	4.0
	NH_4 H_2 PO_4	115.08	1,000	115.08	2.0
	$MgSO_4$. $7H_2O$	246.48	1,000	246.49	1.0
Micronutrients	KCl	74.55	25	1.864	2.0
	H_3BO_3	61.83	12.5	0.773	
	$MnSO_4$. H_2O	169.01	1.0	0.169	
	$ZnSO_4$. $7H_2O$	287.54	1.0	0.288	
	$CuSO_4$. $5H_2O$	249.68	0.25	0.062	
	H_2MoO_4	161.97	0.25	0.040	
	NaFe EDTA	558.50	53.7	30.0	0.3

3.3.1.1- Energy Calculation:

To determine the number of modules according to the output power of pump:

$P = V \times I_{Ac}$

$P_{Dc} = P_{Ac}$

P_{AC}: total power for AC motor pump.

V: AC Voltage.

I: Required current for AC motor pump.

P_{DC} : Total required power for DC modules.

Energy calculation according to (Ahmed and Schemid, 2002):

$E_{gen} = P_{peak} \times PSSH \times F_{th} \times \eta_b \times \eta_{inv}$

P_{peak} : photovoltaic module peak power (W), PSSH : average peak sunshine hour (hr), F_{th}: the PV array thermal factor, η_b: battery efficiency, η_{inv}: inverter efficiency.

Hydroponic calculation:

Using hydroponics systems, mineral nutrients are dissolved in water and feed directly to a plant's root system allowing the plants to focus their energy into growing mostly upward, promoting quicker growth, faster harvests and higher yields. Six PVC pipes (each one with four inches, diameter and 3 m, length were cultured with cucumber seedlings (15 days, age) at the large scale model (from October to December 2013), each pipe has seven culture slots, each slot with five cm diameter, and about 40 cm space between each culture slot. But the one PVC pipe was planted with mint seedlings (20 days, age) at small scale-model (from February to April 2014), the pipe dimension and culture distances between each seven slots are the same for the large scale model. The solution flow rate was estimated according the daily solar radiation's area.

Determinations:

Water consumption

The water consumption average for each plant was calculated every ten days (liter/day) for each scale. The water consumption was calculated by the shortage difference in nutrient solution volume between the two tanks. Also, the Water - Use Efficiency (WUE) was calculated for each plant, as mentioned by (**Tawfiq *et al.* 2007**).

Water Use Efficiency (WUE):

$$(\text{WUE})\ \text{g/liter according to}\ (\textbf{Tawfiq et al., 2007}) = \frac{\text{mass of mature plant (g/plant)}}{\text{volumetric water consumption during plant growth (liter/plant)}}$$

Leaf area:

The average leaf area was determined for cucumber and mint according to (**Shabana and Antoun, 1980**), which the length and width of many leaves for cucumber and mint were measured, as shown in fig. 17 then the average leaf area was determined by the following equation according to (**Shabana and Antoun, 1980**):

$$\textbf{Leaf Area} = \textbf{Length} \times \textbf{Maximum Width} \times \textbf{0.84}$$

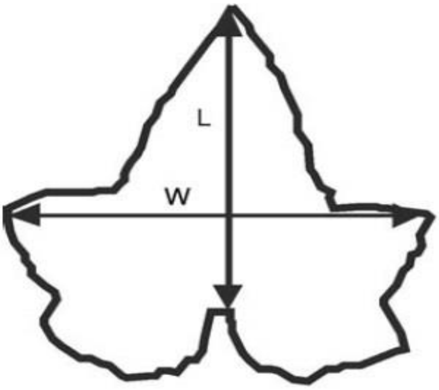


Fig.(6) Diagram of cucumber leaf showing positions of length (L) and width (W) measurements.

Yield:

The cucumber fruits were determined at the end of growing season. Also, the total fresh weight for whole mint plant was determined at the end of growing season.

Cost analysis:

The operating cost of two solar pumping systems under experimental work's conditions were estimated, as shown, 1- **Large scale-model:**

Item	**Price (L.E)**
Solar Modules (4 modules)	4000
Charge Controller	1310
Inverter	750
AC Motor	400
PVC Pipes	360
Tanks	300
Connections	150
Hogland Solution	600
Cucumber Seedlings	130
Total	**8000**

2- **Small Scale-model:**

Item	**Price (L.E)**
Solar Module	1000
DC Motor	85
PVC Pipe	60
Tanks	50
Connections	20
Hogland Solution	250
Mint Seedlings	35
Total	1500

Two methods were used to estimate the operating cost for two systems, by following these equations:

1- **The operation cost was estimated according to Awady (1978),**

$$C = \frac{P}{h}\left(\frac{1}{e} + \frac{i}{2} + t + r\right) + (hp \times S) + (\frac{W}{144} \times 0.1)$$

Where:

P: Capital investment for handling machine, h: Yearly operating hours for handling machine, e: Life expectancy for equipment in general, i: Interest rate, t: Taxes and overheads ratio, r: Maintenances and repairs ratio of the total investment, hp: Power of electric motor, S: Power production price rate, W: Wage of operation and 144: Hours / month.

2- **Cost analysis according to (AbdEl-Rehim et al.,2007):**

Total Cost = Capital Cost + Maintenance Cost + NFT. Cost.

4-RESULTS AND DISCUSSION

Solar and pump units performance

1-The effect of hourly solar radiation on motor discharge rate:

a) Large scale-model:

In this system, the solution flow rate was determined during the experiment's months, (October, November and December, 2013), with the daily solar radiation. The results show the increase of flow rate with the daily solar radiation, as shown in figs (7), (8) and (9).

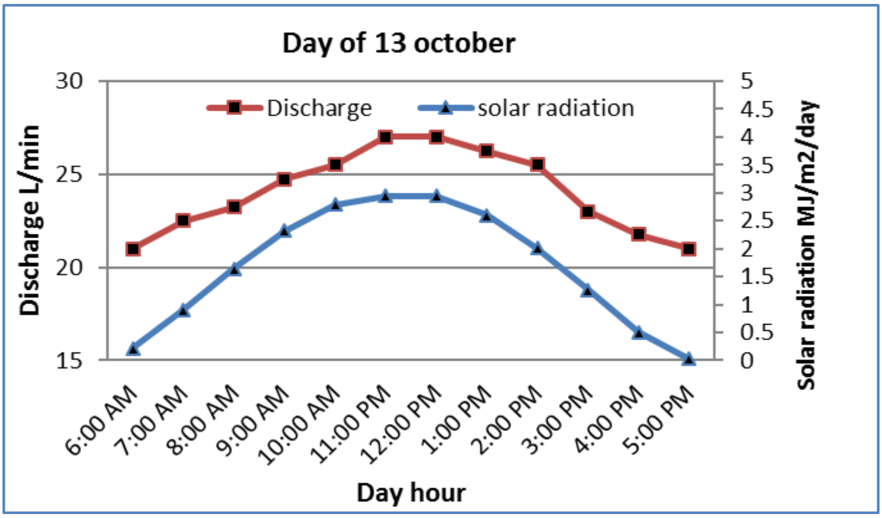


Fig.(7): Hourly average radiation for 13 October (obtained from Meteorological Authority) and the variation of AC motor discharge.

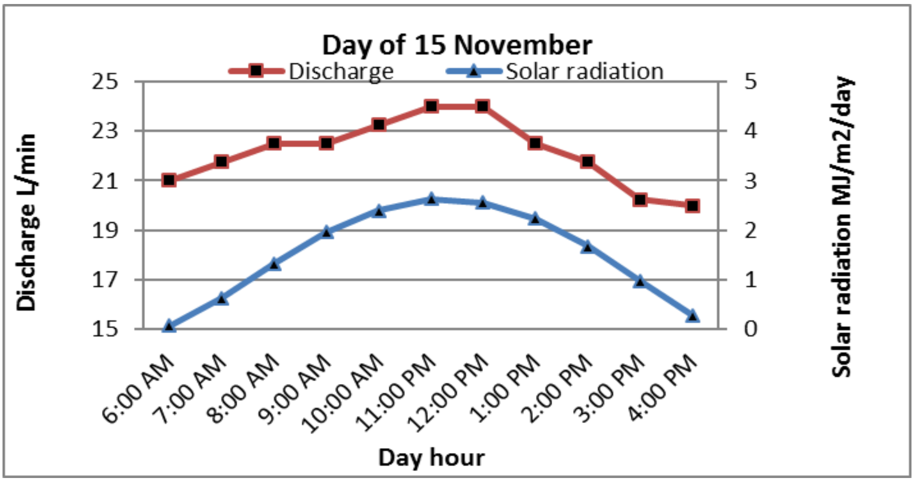


Fig.(8) Hourly Average radiation for 15 November (delivered from Meteorological Authority) and the variation of AC motor discharge.

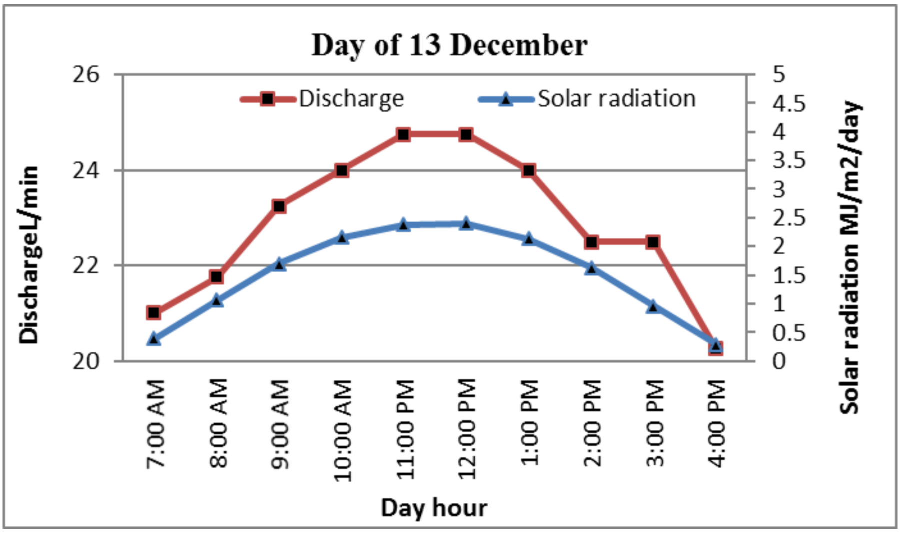


Fig.(9) Hourly Average radiation for 13 December (delivered from Meteorological Authority) and the variation of AC motor discharge.

b) The Small-Scale model:

In this system, the solution flow rate was determined during the experiment's months, (February, March and April 2014), and evaluate this values with the daily solar radiation, also, the results showed that the increase of flow rate with the daily solar radiation increase, as shown in figs, (10), (11) and (12).

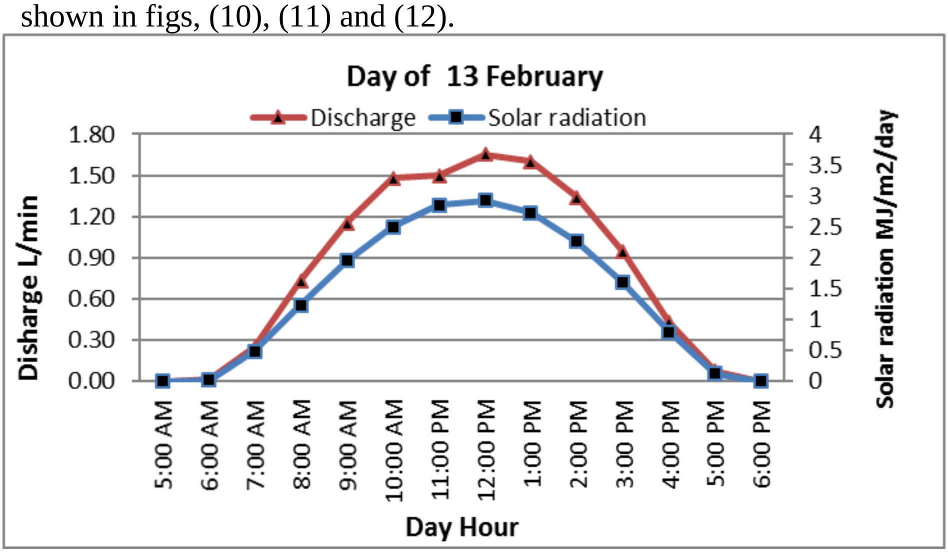


Fig.(10): The discharge with hourly average radiation (data of hourly radiation were obtained from Meteorological Authority).

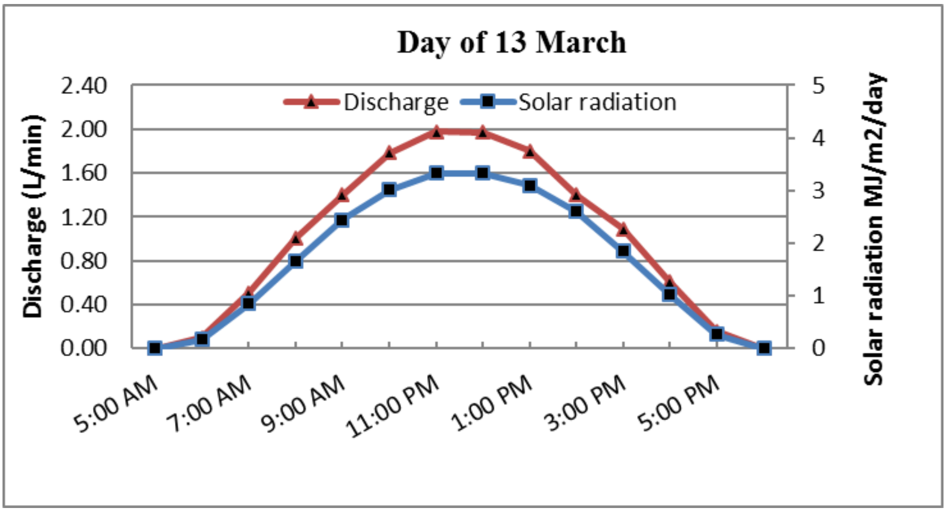


Fig.(11) The discharge with Hourly Average radiation for 13 March (hourly average radiation data were get from Meteorological Authority.

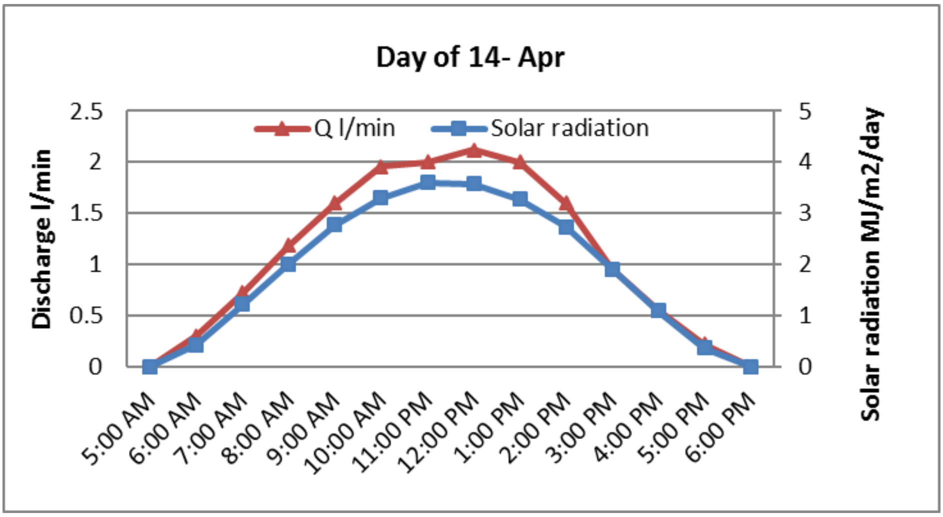


Fig.(12) The discharge with Hourly Average radiation for 14 April (hourly average radiation data were get from Meteorological Authority).

DC motor in this scale showed a good response with daily solar radiation value as it affects clearly on motor's rpm. Accordingly, discharge changed during the day hours.

The large scale model showed that the maximum solution flow rate for (AC) motor pump was 27 liter/min at the maximum daily solar radiation

(2.95 MJ/m^2/day) at 12:00 pm in 13th October (2013) as in fig. (7), 24 liter/min at the maximum daily solar radiation value (2.5 MJ/m^2/day) at 12:00 pm in 15th November (2013) as in fig. (8), and 25 liter/min at the maximum daily solar radiation (2.3 MJ/m^2/day) at 12:00 in 13th December (2013) as in fig. (9).

The small-scale model showed that the maximum solution flow rate for (DC) motor pump is 1.65 liter/min at the maximum daily solar radiation value (2.9 MJ/m^2/day) at 12:00 pm in 13th February (2014) as in fig. (10), 2 liter/min at the maximum daily solar radiation value (3.2 MJ/m^2/day) at 12:00 pm in 13th March (2014) as in fig. (11), and 2.2 liter/min at the maximum daily solar radiation (3.6 MJ/m^2/day) at 12:00 pm in 14th April (2014) as in fig. (12).

The results are in agreement with those of **(Moharrum, 1999)** and **(Hegazy et al., 2010)**. They reported that the daily discharge of the pump varied according to the increasing and decreasing of the daily solar radiation. This is due to the fact that the pump discharge strongly influenced by motor speed, and motor speed depending upon solar radiation intensity.

2-The effect of hourly average radiation on motor speed (rpm):

The solution flow rate, also, was evaluated with the motor pump speed (rpm), and the results affirmed that the flow rate increases with the motor speed, but the flow rate increase for (DC) pump motor is more effective.

a) The large -scale model:

The results show that the variation of motor speed (rpm) was not large from 6:00 am to 4:00 pm during daily solar radiation.

b) The small-scale model:

In this small-scale show the daily solar-radiation values affect clearly on motor's speed. The discharge changed accordingly the day hours as previously mentioned.

The small-scale model results showed that the maximum motor pump speed (rpm) for (DC) motor pump was 22 rpm at the maximum daily solar radiation value (2.9 MJ/m^2/day) at 12:00 pm in 13th February (2014) as in fig. 20, 22 rpm at the maximum daily solar radiation value (3.2 MJ/m^2/day) at 12:00 pm in 13th March (2014) as in fig. 27 in appendix, and 21 rpm at the maximum daily solar radiation (3.6 MJ/m^2/day) at 12:00 pm in 14th April (2014) as fig. 28 in the appendix. This result is in agreement with this of (**Hegazy et al., 2010**), who reported that rpm for DC motor is actually influenced by solar radiation.

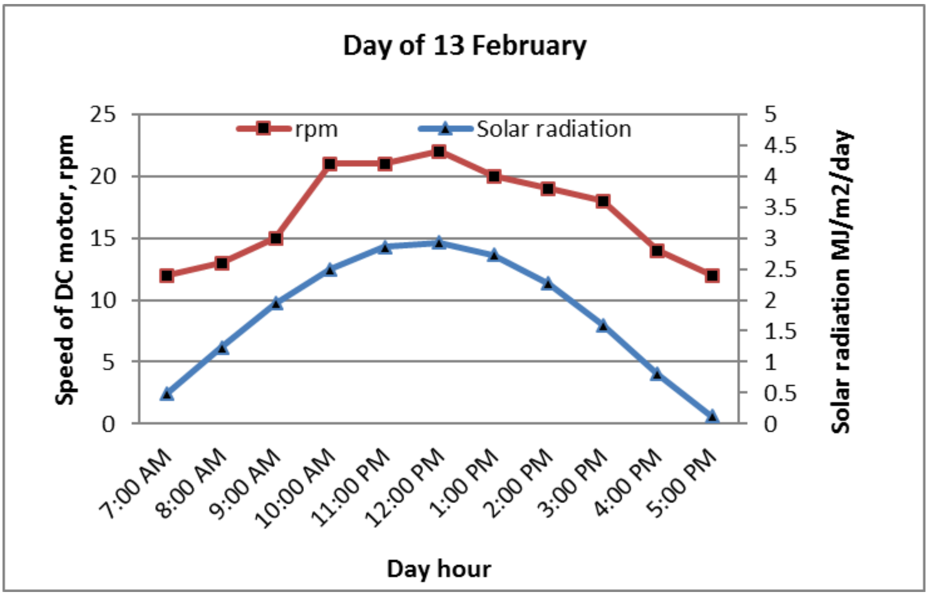


Fig. (13) Rpm values with hourly average radiation for 13th February.

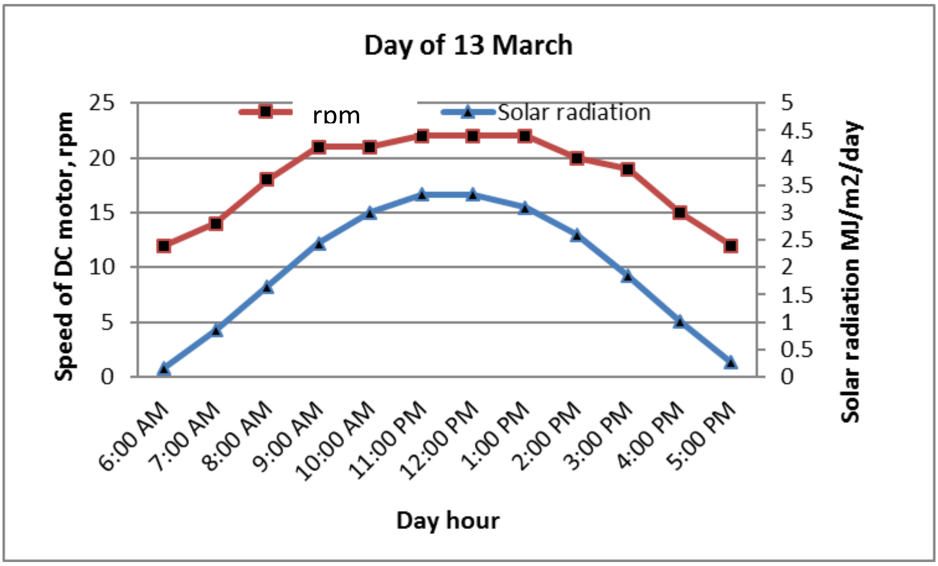


Fig.(14):Rpm value with hourly average radiation for 13 March

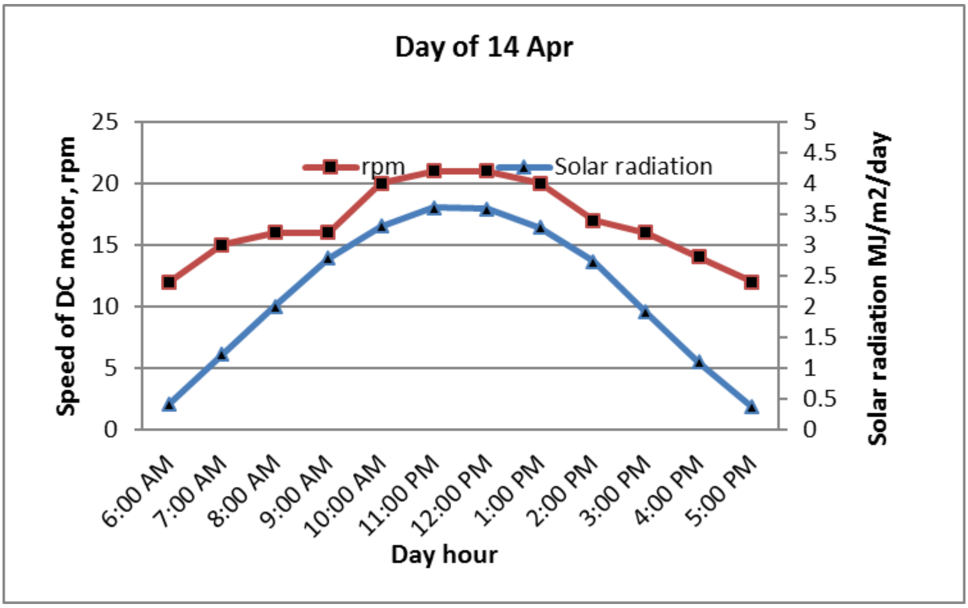


Fig.(15)Rpm values with hourly average radiation for 14th April.

Energy Calculations for large-scale model:

The energy needs were estimated by the following two equations:

Energy calculation according to (Ahmed and Schemid, 2002) :

$E_{gen} = P_{peak} \times PSSH \times F_{th} \times \eta_b \times \eta_{inv}$

$E_{gen} = (4\times75) \times 7 \times 0.85 \times 0.9 \times 0.95 = 1526$ W.h/day, this value is act the power generation from four PV modules/day.

$(P_{Motor})_{day} = 375 \times 3 = 1125$ W.h/day, this value is act the required power to run the solar motor-pump (375W)/day. (For 3 hours operating time only per day).

Or:

$P_{DC} = V \times I_{DC}$

$I_{DC} = P/V = 300$ (for 4 modules)/17 = 17.6 Amp.h.

$(I_{DC})_{day} = 17.6 \times 7 \times 0.85 = 92.4$ Amp/day (7→ radiation hours/one day, 0.85→the efficiency of the solar system), 92.4 is act the current generation from four PV modules/day.

$I_{AC} = 375/220 = 1.704$ Amp.

$I_{DC} = 1.7 \times 10 = 17.04$ Amp.   10 → constant to convert AC to DC.

$(I_{DC})_{day}$ = 17.04 × 3 = 51.12 Amp.h/day, (three is operating hours/day), 51.12 is act the required current to run the solar motor-pump/day.

Hydroponic performance:

The two systems (large and small) showed good response for plants growth under hydroponic system and the area's conditions, without use of any pesticide. Water consumption per plant was calculated from the period of planting until full maturity, as well as the water use efficiency (WUE) on the basis of the fresh crop. The average leaf area per plant was also calculated, from the areas of leaves for many output plants and taking the average of area per plant.

1- Water consumption

a- Large – scale model:

In this scale, cucumber water consumption in liters/10days and cumulative water consumption in liters/90 days during (October to December 2013) were calculated, as shown in fig (21).

The results show an increase in water consumption in liters per plant/10 days during culture season, the maximum water consumption in liters was 8 liters/plant/10 days in last ten days (81-90 days).

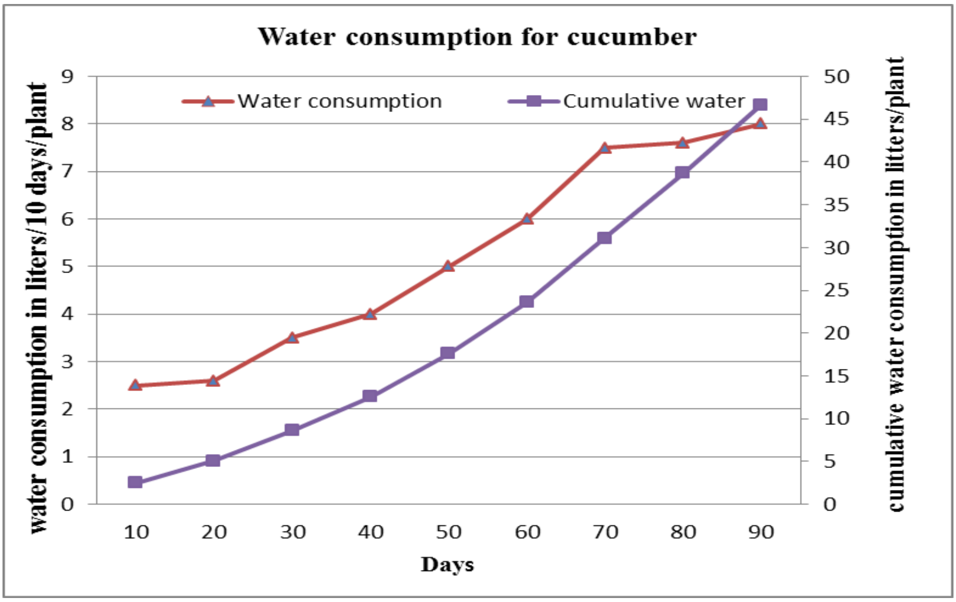


Fig (16): Cucumber water consumption for 90 days.

b- Small- scale model:

In this model, water consumption in liters/10 days and in liters/90 days for mint during (February to April 2014) were determined, as shown in fig (22).

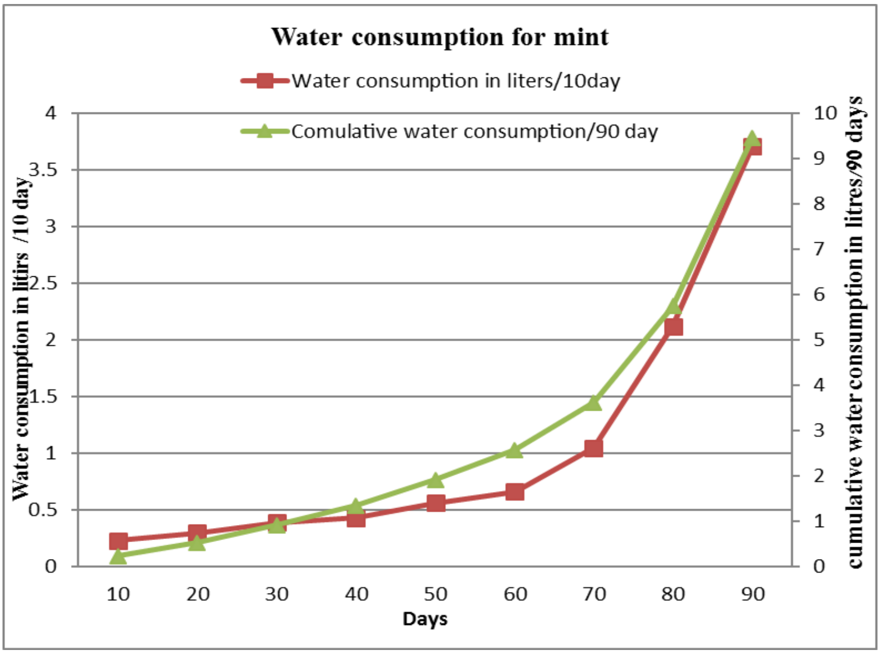


Fig (17): Mint water consumption during 90 days.

The results showed that, there was increasing in water consumption. The maximum water consumption was 3.6 liters/plant/10 days in the last ten days and 9.5 liters per plant/90 days during season. These results agree with **Tawfiq et al. (2007)**, who reported increasing in water consumption for mint plant during culture season.

2-WUE:

a- Large –scale model (for cucumber):

Fresh mass for cucumber fruits/plant was determined at the end of culture season; it was 2500 g/plant, so,

(WUE) cucumber = 2500 (g/plant) / 46.7 (L/plant) = 53.5 g/liter.

b- Small –scale model (for mint):

Fresh mass for mint was determined at the end of culture season; it was 400 g/plant, so,

(WUE) for mint = 400 (g) / 9.45 (liter) = 42.328 g/liter.

3-Leaf area:

For two scales, average leaf area for cucumber and mint were determined according to **(Shabana and Antoun, 1980):**

Length and width of the leaves for many plants (cucumber and mint) were measured, and the average leaf area was calculated for each plant.

a- large- scale model:

The average value of leaf area after 90 days plant age for cucumber is (196.08 cm^2).

Gallardo *et al.* (1996), El-Shinawy (1997), Wang and Zhang (2004) and Hesham (2007) reported that water consumption for cucumber plant increased the total leaf area per plant and fresh weight.

b-Small –scale model:

The average value of leaf area after 90 days plant age for mint is (2.7 cm^2).

4-Yield:

At the end of growing season, the yield of cucumber and mint were determined, the cucumber fruits is 2500 g/plant at the end of culture season (90 days). Also, the whole mint plant is 400 g/plant at the end of the season (90 days).

Cost Analysis:

a) First – large Scale:

1- Cost analysis according to (Awady 1978):

P → 8000 L.E (5000PV – 3000 other components), **h** → 2190, **e** → 10 for PV and 5 for other components., **i** → 12%, **t** → 0.05, **r** → 0.1, **hp** → 0.375 W, **s** → 1.6 (NFT cost), **w** → 500

Cost per hour for PV modules "C" = 5000/2190 (1/10 + 0.12/2 + 0.05 + 0.1) + (500/144) X 0.1 = 1.05 L.E./h.

Where (0.1) is the operating hours during day constant by worker in case of solar systems, because these systems don't need workers compared with traditional systems.

Cost per hour for other components "C" = 3000/2190 (1/5 + 0.12/2 + 0.05 + 0.1) + (1.6) = 2.16 L.E./h.

2- Cost analysis according to(AbdEl-Rehim 2007):

Total Cost = Capital cost + Maintenance Cost + NFT Cost

Cost per year =((8000/10) + 100 + (300 ×12)) = 4500 L.E./year.

Cost per day = 4500/365 = 12.32 L.E./day

Cost per hour = 12.64/6 = 2.05 L.E./hr.

b) Small-scale model:

1-Cost analysis according to(Awady 1978):

P → 1500L.E. (1000PV – 500 other components), **h** → 750, **e** → 10 for PV and 5 for other components, **i** → 12% , **t** → 0.05 , **r** → 0.1, **hp** → 30 Watt, **s** → 0.54 (NFT cost), **w** → 500

Cost per hour for PV modules "C" = $1000/2190\ (1/10 + 0.12/2 + 0.05 + 0.1) + (500/144) \times 0.1 = 0.486$ L.E./hr

Cost per hour for other components "C" = $500/2190\ (1/5 + 0.12/2 + 0.05 + 0.1) + 0.54 = 0.622$ L.E./hr

2-Cost analysis according to(AbdEl-Rehim 2007):

Total Cost = Capital Cost + Maintenance Cost + NFT Cost

Cost per year = $(1500/10) + 50 + (50 \times 12) = 800$ L.E./year.

Cost per day = $(800/365) = 2.19$ L.E./day.

Cost per hour = $(2.19/6) = 0.365$ L.E./hr.

When the cost of water productivity by this system is compared with other systems next factors should be taken into account.

- The PV module and its component form about 75 % of all capital cost and it provides the system with about125% from required electricity.
- Cost of kWh produced by PV module is equal to 0.50 LE, but at present time, with electricity subsidizing from government 1 kWh is equal to 0.08 LE.
- The system life expectancy was taken as 10 years but in most references it is taken as 15-20 years.
- For the present two systems, the number of growth plants for cucumber and mint in one pipe was about 7 plants, but one pipe can be cultivated until 10 – 12 plants.

Production:

It were planted about 42 plants of cucumber in large-scale model, and 10 plants of mint in small-scale model, so, the total production during the growth season for cucumber and mint in two systems were determined as shown in table (4).

Table (4): Production and costs for cucumber and mint.

Types of plants	Period	First 30 days	Second 30 days	Last 30 days
Cucumber	Production (kg)	70	140	80
	Cost (L.E/kg)	4.12	2.06	3.61
Mint	Production (Kg)	5	5.5	4
	Cost (L.E/kg)	4.2	3.5	3.8

5-SUMMARY AND CONCLUSION

The increase in crops production through nutrient culture systems is mainly an export oriented process for meeting the demand of the increasing Egyptian population and consequently, increasing the food consumption. The use of solar photovoltaic cells as the power source for pumping water is one of the most promising areas in solar photovoltaic applications. With the increasing use of water pumping systems, more attention has been paid to their design and optimum utilization in order to achieve the most reliable and economical operation.

This study aims to evaluate two closed solar pumping systems with hydroponic (NFT) unit using (large and small scale-models with the same mechanism) to present a suitable solution for electricity problem in the remote areas, as well as aims to insert a better style of culture (hydroponic) which saves the water, to the area's study, to solve the water rarity problem in arid areas.

The experimental works were carried out at The New Valley, El-Dakhla, Mut city, and use the municipal water. In both; large scale-model and small –scale model a photovoltaic system is used at large scale system 4 modules of PV (connected in parallel) are used to provide the system with required electricity, each one is (75 watt, Monocrystallene, 12 volt and 4.8 A) with a charge controller (50A) , Battery (100 Ah) and Inverter (300 watt). The culture area was (3 m × 5 m), the testing period was from the first October until the last of December (2013), the upper tank was filled manually with water, and the nutrient solution is added with required rates, the water flows from the upper tank under the gravity via culture pipes (each one with four inches diameter and 3 m length) to the lower one (at ground level, then, the water was lifted to the upper tank by solar motor pump (AC motor pump,375 W, 220 V, 1500 rpm, 2.4 m^3/h), and this recycle repeated many times, and the upper tank compensates the consumed water as a result of water plants consumption by refilling it manually. This system was planted with cucumber seedlings (*Cucumis sativus L, Beta Alpha var.*, 15 days age).

The small scale-model with 1 module of PV and (0.1 m × 3 m) culture area, testing period from February to April 2014), the water lifted by small solar motor pump (DC motor pump, 30 W, 12 V, 22 rpm, 2 l/min) from the ground tank (25 liter, at the ground level) to the upper one (25 liter, 0.5 m high), this system was planted with mint (20 days age).

The effect of some factors on the water flow rate of the two systems were evaluated, these factors were: daily solar radiation and motor speed (rpm), the results indicated that:

1- As daily solar radiation increased, the motor speed (rpm) increased, and consequently the flow rate increased for the two pumping systems, but the increasing of the flow rate for DC motor pump was more effective.
2- The maximum flow rate for direct current (DC) motor pump was 1.65 liter/min; at maximum solar radiation on 13 February 2014 (2.9 MJ/m^2/day) at 12:00 pm, and the maximum flow rate for alternative current (AC) motor pump was 27 liter/min; at maximum solar radiation which was on 13 October 2013 (2.95 MJ/m^2/day) at 12:00 pm.
3- For large scale-model, the variation of motor speed (rpm) for AC motor pump was not large from 6:00 am to 4:00 pm during daily solar radiation, but the small-scale one the variation is clear which the maximum motor pump speed (rpm) for Dc motor pump was 22 rpm at the maximum daily solar radiation (2.9 MJ/m^2/day) at 12:00 pm in 13th February (2014).

For hydroponic performance, the two systems (large and small) showed good response for plants growth under hydroponic system and the area's conditions, without use of any pesticide. As well as, water consumption for cucumber and mint were determined during culture period (90 days), water use efficiency (WUE), average leaf area, the fresh weight for cucumber’s fruits and the total fresh weight for whole mint plant were determined at the end of the culture season, and the results showed that:

4- The maximum water consumption was in the last thirty days of culture season (from 61 – 90 days) for one plant of cucumber and mint, the cumulative water consumption for one plant of cucumber and mint were 46.7 and 9.45 litters respectively.
5- The maximum value of (WUE) for two plants were in the first thirty days of culture season (1 – 30 days) because this value increased with low consumption of water, so, (WUE) for one plant of cucumber and

mint at the end of culture season were 53.5 and 42.3 g/liter respectively.

6- The average leaf area for one plant of cucumber and mint were 196.08 cm^2 and 2.7 cm^2 respectively.

7- The fresh weight for cucumber's fruit was 2500 g/plant, and the total fresh weight for whole mint plant was 400 g/plant.

Recommendations

1-Studies should be focused on the New Valley area to achieve the best use of its resources.

2- Activation of this type of Agriculture (Hydroponics) over large areas of the New Valley area to keep the wasted water of traditional irrigation amounts.

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الملخص العربي

تطوير نظام للزراعة المائية
باستخدام الطاقة المتجددة ليناسب ظروف المناطق النائية

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ان الزيادة في انتاج المحاصيل عن طريق أنظمة الغشاء المغذي تعتبر عملية اساسية موجهة للتصدير للخارج, لتلبية الطلب المتزايد على الغذاء من سكان جمهورية مصر العربية.
يعد استخدام الخلايا الشمسية كمصدر بديل للطاقة التقليدية في أنظمة ضخ المياه, واحدا من أهم الاستخدامات الواعدة في تطبيقات الأنظمة الشمسية, حيث مع زيادة استخدام أنظمة الضخ ازداد مع توجيه الأنظار للاهتمام بتصميم هذه الأنظمة (أنظمة الضخ الشمسية) بشكل أكثر فعالية لتحقيق الاستفادة القصوى منها, وبالتالي تحقيق عائد اقتصادي مناسب.

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تهدف هذه الدراسة إلي تقييم نظامين لضخ المياه بالطاقة الشمسية تحت ظروف منطقة الوادي الجديد, وهذان النظامين هما نموذج كبير وآخر صغير لهما نفس طريقة التصميم والتشغيل,كل منهما يعتبر نظام مغلق للزراعة المائية (NFT) وهو نظام تقنية الفيلم المغذي, وذلك للمساهمة في تقديم حل مناسب لمشكلة الكهرباء بالمناطق النائية, بالاضافة الي ادخال نوع حديث من الزراعات وهو الزراعة المائية والتى تعمل على توفير كميات المياه من اجل حل مشكلة ندرة المياه لمنطقة الدراسة.

أجريت التجارب العملية بمحافظة الوادي الجديد, مركز الداخلة, مدينة موط, وقد تم إنشاء النظامين السابقين بنفس التصميم, ولكن النظام الأول في الفترة من بداية شهر أكتوبر حتى شهر ديسمبر لعام ٢٠١٣, حيث تم استخدام ٤ موديولات شمسية ، متصلة مع بعضها على التوازي, كانت مواصفات الموديول الواحد (٧٥ وات, ١٢ فولت, ٤,٨ أمبير)، تم استخدام منظم شحن (٥٠ أمبير), بطارية (١٠٠ أمبير/ساعة), انفرتر (٣٠٠ وات), لتكون بذلك الوحدة الشمسية مكتملة والتى استخدمت لأدارة مضخة ري شمسية ذو التيار المتردد، مواصفاتها (٣٧٥ وات، ٢٢٠ فولت، ١٥٠٠ لفة/دقيقة، ٢,٤ م٣/ساعة, ٣٠ م ضاغط) والمستخدمة في نظام للزراعة المائية (NFT) على مساحة (٣م × ٥م)، يتم ملئ الخزان العلوي باستخدام مياه البلدية (خزان التغذية, بارتفاع ٥ر١ م عن سطح الأرض, بحجم ٣٠٠ لتر) يدويا ثم إضافة المحلول المغذي بالمعايير المطلوبة الي الخزان, وبعدها يتم انسياب المحلول المغذي مارا بخطوط الزراعة (قطر كل منها ٤ بوصة, وبطول ٣ م) والمحتوية على شتلات الخيار (عمر ١٥ يوم), ومنها إلى الخزان الأرضي (خزان التجميع, مساوي لمستوي سطح الأرض, بحجم ٣٠٠ لتر), بعد ذلك يتم إعادة تدوير المحلول المغذي منه إلى خزان التغذية مرة أخري عن طريق المضخة الشمسية، وتتكرر هذه الدورة عند ري الشتلات.

والثاني نموذج مصغر له على مساحة (٥ر٠ م × ٣ م) في الفترة من بداية شهر فبراير و حتى نهاية شهر ابريل لعام ٢٠١٤, حيث استخدم موديول واحد بنفس مواصفات الموديول في النظام السابق, والذي استخدم معه منظم للشحن (٥ أمبير)، وبطارية (١٠٠ أمبير/ساعة)، استخدمت هذه الوحدة لأدارة مضخة ري صغيرة من نوع التيار المستمر (٣٠ وات، ١٢ فولت، ٢٢ لفة/دقيقة، ٢ لتر/دقيقة)، اعتمد انسياب المحلول بنفس الطريقة السابقة للنظام الأول, من خلال انسيابه من خزان التغذية (٢٥ لتر, وبارتفاع ٥ر. م عن سطح الأرض, مارا بخط واحد للزراعة (بقطر ٤ بوصة , بطول ٣ م), والمحتوي علي شتلات النعناع (عمر ٢٠ يوم), ومنه إلى خزان التجميع وهو بنفس مواصفات خزان التغذية ولكنه مساوي لمستوى سطح الأرض, والذي يتم إعادة تدوير المحلول المغذي منه إلى خزان التغذية مرة أخرى بواسطة المضخة الشمسية الصغيرة وتتم تكرار هذه الدورة عند ري الشتلات.

تم تقييم بعض المعاملات على معدل تصرف المحلول للنظامين، هذه المعاملات هي : الاشعاع الشمسي اليومي، سرعة الوران لمحرك المضخة لكلا النظامين، أشارت النتائج الي:

١- أظهرت نتائج كل من النظامين استجابة جيدة مع التغير في كل من هذه العوامل, حيث بزيادة معدل الإشعاع الشمسي اليومي وكذلك عدد اللفات في الدقيقة لكل من الموتورين,

زاد معدل تصرف كل منهما, مع ملاحظة أن زيادة معدل التصرف للموتور ذو التيار المستمر كانت ملحوظة عن زيادة معدل التصرف للموتور ذو التيار المترددز

٢- أقصى معدل التصرف للموتور الأول (ذو التيار المستمر) كان ١,٦٥لتر/ دقيقة عند أقصى قيمة للإشعاع الشمسي ليوم ١٣ فبراير ٢٠١٤ وهى ٢,٩ ميجا جول/م^٢/يوم في تمام الساعة ١٢:٠٠ ظهرا, وكان معدل التصرف للموتور ذو التيار المتردد (AC) ٢٧ لتر/ دقيقة عند أقصى قيمة للإشعاع الشمسي ليوم ١٣ أكتوبر ٢٠١٣ وهي ٢,٩٥ ميجا جول / م^٢ / يوم.

٣- بالنسبة للنظام الكبير كان معدل التغير في سرعة دوران الموتور ذو التيار المترر كانت غير ملحوظة من الساعة ٦ صباحا وحتى الساعة الرابعة مساءا خلال ساعات اليوم، بينما النموذج الصغير كان معدل التغير في سرعة دوران الموتور ذو التيار المستمر كانت ملحوظة خلال ساعات اليوم مع تغير معدل الاشعاع الشمسي، حيث كانت سرعة دوران الموتور ٢٢ لفة/دقيقة عند اعلى قيمة للاشعاع الشمسي ٢,٩ ميجا جول/م٢/يوم عند الساعة ١٢ ظهرا ليوم ١٣ فبراير ٢٠١٤.

بالنسبة لأداء وحدة الزراعة المائية، أظهر كل من النظامين استجابة جيدة لنمو نباتي الخيار والنعناع تحت ظروف الزراعة المائية وظروف منطقة الدراسة، قد تم حساب الاستهلاك المائي لنباتي الخيار والنعناع خلال موسم الزراعة (٩٠ يوم)، وأيضا كفادة استخدام المياه، متوسط مساخة الورقة لكل من النباتين، بالاضافة الى الوزن الطازج لكل من ثمار الخيار، نبات النعناع بأكمله، في نهاية موسم الزراعة، وكانت النتائج كالتالي:

٤- كان أقصى استهلاك مائي في اخر ٣٠ يوم (من ٦١ – ٩٠ يوم) للنبات الواحد لكل من الخيار والنعناع، وكان الاستهلاك المائي الكلي لنبات الخيار والنعناع بعد نهاية موسم الزراعة ٤٦,٧ لتر، ٩,٤٥ لتر على الترتيب.

٥- أقصي قيم لكفاءة استهلاك المياه لكلا النباتين في اول ٣٠ يوم (١ – ٣٠ يوم) من عمر النباتين, وكانت قيم استهلاك المياه لكلا من نباتي الخيار والنعناع ٥٣,٥ جم/لتر ، ٤٢,٣ جم/لتر على الترتيب في نهاية موسم الزراعة.

٦- كانت قيم متوسط مساحة الورقة لكل من نباتي الخيار والنعناع ١٩٦,٠٨ سم٢، ٢,٧ سم٢ على الترتيب.

٧- الوزن الطازج لثمرة الخيار الواحدة كانت ٢٥٠٠ جم/للنبات الواحد، الوزن الطازج لنبات النعناع بأكمله كانت ٤٠٠ جم/للنبات الواحد.

التوصيات

١- لابد من تفعيل الدراسات العلمية و الأبحات على منطقة الوادى الجديد لتحقيق أقصى استفادة من مواردها.

٢- تفعيل هذا النوع من الزراعات (الزراعة المائية) على مساحات اكبر في منطقة الوادي الجديد للحفاظ على كميات المياه من الهدار وأيضا للمساهمة في انتاج محاصيل جديدة وتحقيق الاكتفاء الذاتي.