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Abdeljaleel & Zeinaldeen

المجلة العراقية لبحوث السوق
وحماية المستهلك

ESTIMATING THE ENERGY COST AND SYSTEM EFFICIENCY FOR SOLAR DRIP IRRIGATION SYSTEM

***Mustafa T. Abdeljaleel**[*1]**, Laith A. Zeinaldeen**[2]*

[1] Researcher, Department of Agriculture Machines and Equipment, College of Agriculture Engineering Sciences, University of Baghdad, Baghdad, Iraq. Mostafa.abd2203m@coagri.uobaghdad.edu.iq

[2] Assistant Professor PhD., Department of Agricultural Machines and Equipment, College of Agricultural Engineering Sciences, University of Baghdad, Iraq. laith.a@coagri.uobaghdad.edu.iq

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ABSTRACT

In order to estimate the energy cost and system efficiency for solar drip irrigation system. The experiment was carried out at the Al-Raed research station located in the Abu Ghraib area, west of Baghdad, for the fall season of 2023. A randomized complete block design (RCBD) with three replicates was used the least significant difference of 0.05 was used. The experiment consisted of three factors: The first factor was the solar panel type with two levels: monocrystalline and polycrystalline. The second factor was operating pressure of Irrigation system with two levels P1 (0.25 bar) and P2 (0.5 bar). The third factor was the dripper type with three levels: T1(4 L/hr.), T2(8 L/hr.), and T3(16 L/hr.). The following indicators were studied: Solar panel power(watt), energy cost ($/KWh), Irrigation system efficiency (%) and germination percentage (%). The results showed the highest results in solar panel power (1191watt), irrigation system efficiency (84.22%), germination percentage (86.11%) with the lowest power costs (0.230 $/KWh) achieved by the monocrystalline solar panel. Achieving the highest solar panel power (1156watt), the highest irrigation system efficiency (83.86%), and the highest germination percentage (83.68%) with the lowest energy costs (0.289 $/KWh) at the operating pressure P2. The dripper type T2 achieved the highest solar panel power (1157watt), the highest irrigation system efficiency (84.42%) and the highest germination percentage (86.46%).

Keywords: Dripper, Energy cost, Germination percentage, Solar panel

تخمين تكاليف الطاقة وكفاءة النظام لمنظومة ري بالتنقيط تعمل بالطاقة الشمسية

مصطفى ثائر عبد الجليل[1] ، ليث عقيل الدين زين الدين[2]

[1]الباحث، قسم المكائن والألات الزراعية، كلية علوم الهندسة الزراعية، جامعة بغداد، بغداد، العراق، Mostafa.abd2203m@coagri.uobaghdad.edu.iq

[2]استاذ مساعد دكتور، قسم المكائن والألات الزراعية، كلية علوم الهندسة الزراعية، جامعة بغداد، بغداد، العراق، laith.a@coagri.uobaghdad.edu.iq

الخلاصة

بهدف تخمين تكاليف الطاقة وكفاءة النظام لمنظومة ري بالتنقيط تعمل بالطاقة الشمسية. تم تنفيذ التجربة في محطة ابحاث الرائد الواقعة في منطقة ابو غريب غرب بغداد للموسم الخريفي 2023. تم استخدام تصميم القطاعات العشوائية الكاملة (RCBD) بثلاثة مكررات وتم استخدام اقل فرق معنوي (0.05). تكونت التجربة من ثلاثة عوامل: العامل الأول هو نوع الألواح الشمسية بمستويين: أحادي التبلور ومتعدد التبلور. العامل الثاني هو ضغط التشغيل لنظام

[*] **This article is taken from the first researcher's master's thesis.**

الري بمستويين P1 (0.25 بار) وP2 (0.5 بار). العامل الثالث هو نوع المنقط بثلاثة مستويات: T1(4 لتر/ساعة)، T2(8 لتر/ساعة)، وT3(16 لتر/ساعة). تمت دراسة المؤشرات التالية: قدرة اللوح الشمسي (واط)، تكاليف الطاقة (دولار/كيلوواط ساعة)، كفاءة نظام الري (٪) ونسبة الإنبات (٪). وتظهر النتائج تحقيق أعلى قدرة اللوح الشمسي (1191 واط)، وكفاءة نظام الري (84.22%)، ونسبة الإنبات (86.11%)، مع أقل تكلفة طاقة (0.230 دولار/كيلوواط ساعة) حققتها الألواح الشمسية أحادية البلورية. تحقيق أعلى قدرة للوح الشمسي (1156 واط) وأعلى كفاءة لنظام الري (83.86%) وأعلى نسبة إنبات (83.68%) مع أقل تكلفة طاقة (0.289 دولار/كيلوواط ساعة) عند ضغط التشغيل P2. حقق المنقط نوع T2 أعلى قدرة للوح الشمسي (1157 واط) وأعلى كفاءة لنظام الري (84.42%) وأعلى نسبة إنبات (86.46%).

الكلمات المفتاحية: المنقط ، تكاليف الطاقة ، نسبة الانبات، اللوح الشمسي.

INTRODUCTION

The excessive use of fossil fuels since the industrial revolution led to raise the global temperatures, which caused the global warming that the world is experiencing **(Mahal *et al.,* 2022)**. Due to the negative effects of global warming, the continuous use of renewable energy is increasingly taking place, and one of the most important sources of renewable energy is solar energy due to its effectiveness in the environment and economical in terms of the cost of producing photovoltaic energy **(Başaran *et al.,* 2020).** The consumption of photovoltaic energy is less than the consumption of traditional energy that runs on electricity and fuel **(Maurya *et al.,* 2015).** Increasing the temperature of panels beyond 30°C can lead to a reduction in panel performance and power output by more than 50% **(Zeinaldeen, 2020)** . According to the study and the results that appeared, the cost of a Kw/h for solar-powered stations is the lowest compared to stations that operate with fossil fuels **(Sovacool, 2009).** As the operating pressure increases, the dripper discharge increases **(AL-Mhmdy & AL-Dulaimy, 2018).** One of the advantages of the drip irrigation system that works with solar panels is that it increases yields with less water consumption and less energy costs **(Grant, *et al*., 2022)**. Increasing the efficiency of irrigation systems is one of the main goals that farmers seek to increase cultivated areas while reducing water consumption (**Abdullah & Kadhimm, 2023).** The drip irrigation system is considered one of the most efficient modern irrigation systems that has a role in technicalizing irrigation water to reduce water losses **(Khattab & El-Housini, 2019).** Providing irrigation water in quantities appropriate for the plant when using modern irrigation systems, where water is rationed, which makes the efficiency of the irrigation system better than traditional irrigation methods **(Rasheed, 2021).** The results showed that the drip irrigation system was superior to the sprinkler irrigation system in reducing water consumption and losses in conditions of water scarcity **(Al-Lami *et al*., 2023**). There is a significant increase in the efficiency of water use in drip irrigation and irrigation of exudation, this is what we found **(Aldulaimy *et al.,* 2018).** Sunflower is an oil crop, it is grown in central Iraq, the lack of water does not affect the crop or the efficiency of irrigation, as it is watered at appropriate times and distributed homogeneously in the field **(Ahmed, 2012).** The increase in sunflower yield results from an increase in the number of plants per unit area

(**Tawfiq, 2019).** To grow varieties of agricultural crops that can withstand the climate of Iraq, we recommend planting them in different places and times and studying some of the characteristics, including their ability to tolerate drought **(Khalaf & Hassan, 2022).**

Research problem:

Relaying on energy sources was one of the most important challenges facing the humanity, to solve the issue of global warming because of counting on fossil fuels (diesel, gasoline, gas, etc.) as a source of energy. In addition, global warming has affected climate change, leading to less rainfall, which requires the need to work on finding regulated irrigation methods for water to benefit from it to reduce the phenomenon of water scarcity. For all the above, the idea of research came about.

Research objective:

- Performance comparing of two types of solar panels (monocrystalline and polycrystalline).
- Estimating the best irrigation operating pressure.
- Select the best dripper type.
- Determine the best solar panel type that achieves the highest capacity with the lowest operating costs.
- find the best combination between the solar panel type and the dripper type with the best operating pressure.

MATERIALS AND METHODS

An experiment was carried out at the Al-Raed research station located in the Abu Ghraib area,20 km west of Baghdad, for the fall season of 2023. A randomized complete block design (RCBD) with three replicates was used. In order to estimate the energy cost and system efficiency for solar drip irrigation system. The experiment consisted of three factors: The first factor was the solar panel type with two levels: monocrystalline and polycrystalline. The second factor was operating pressure of Irrigation system with two levels P1 (0.25 bar) and P2 (0.5 bar). The third factor was the dripper type with three levels: T1(4 L/hr.), T2(8 L/hr.), and T3(16 L/hr.). To investigate the characteristics listed below: Solar panel power(watt), energy cost ($/KWh), Irrigation system efficiency (%) and germination percentage (%). Many agricultural operations were carried out on the soil of the experimental field in terms of the process of the soil was plowed with moldboard Plow, a rotary harrow was used to soften the soil, and then a land plan was used to avoid rises and dips in the soil. Soil samples were taken and sent to the station laboratory for the purpose of determining the physical and chemical characteristics of the soil, as shown in Table (1). On the date 10/8/2023 in the soil of the station Al-Raed Planting was done with a seed drill, SAKALAK (SKPMD 4G) using sunflower seeds type (KALAMIS). It was planted at a depth of (3-5 cm), and 2 seeds were placed in each hole. The field was divided into 36 experimental units, 10 m long and 1.4 m wide. The experimental unit consisted of Three lines, the length of the line is 10 m, the distance between one line and another is 70 cm, and the distance between one plant and another is 25 cm. Three weeks after planting, the germination rate was taken, and the harvesting process took place on 12/5/2023.

Table (1): Soil chemical and physical characteristics for study field.

Soil depth	**Soil articulations $g.kg^{-1}$**			**Soil texture**	**Field volumetric water content at 33 Kps (Cm^3Cm^{-3})**	**Volumetric water content at 1500 Kps (Cm^3Cm^{-3})**	**PH**	**EC $dS.m^{-1}$**	**Soil bulk density $Mg.m^{-3}$**
	Sand	**Silt**	**Clay**						
0 – 25	12	52	35	Silty clay loam	0.465	0.265	7.7	8	1.27
25 - 50	11	51	36	Silty clay loam	0.470	0.274	7.4	16	1.31

CHARACTERS STUDIED:

SOLAR PANEL POWER (Watt)

The solar panel power was measured according to the following equation **(Manfaluthy *et al*., 2019)**

$$P_{max} = V_{mp} * I_{mp} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where:

P_{max} = Maximum solar panel power (Watt).
V_{mp} = Maximum power Voltage (Volt).
I_{mp} = Maximum power Current (Ampere).

ENERGY COSTS ($/KWh)

Energy costs ($/KWh) were calculated by extracting the power (watt) according to Equation No (1) and converting it to (KWh), then multiplying it by the operating times during the season. Then, we extract the energy costs by dividing the purchase price ($) by (KWh), using the following equations **(Maurya *et al*., 2015).**

$$E_{cost} = Pr / P_s \quad \ldots\ldots\ldots\ldots (2)$$

Where:

E_{cost} = Energy costs ($/KWh).
Pr = Purchasing price ($).
P_s = solar panel power (Watt).

IRRIGATION SYSTEM EFFICIENCY (%)

The efficiency of the irrigation system was measured according to the equations used before (Al-Taif & Al-Hadithi, Irrigation basics and applications, 1988)

Ie = Pe * De * 100 ………. (3)
Since:
Ie = Irrigation system efficiency (%).
Pe = Perfusion efficiency (%).
De = Distribution efficiency (%).
We extract (Pe) from the following equation:
Pe = (Ws / Wf) *100
Where:
Pe = Perfusion efficiency (%).
Ws = Water depth in the root zone(m).
Wf = The quantity of water arriving from the source(m).
We extract (De) from the following equation:
De = (1-ȳ / ẟ) *100 ………. (4)
Where:
De = Distribution efficiency (%).
Ȳ = Deviation coefficient (cm).
ẟ = The rate of depth of water in the soil in irrigation (cm).

GERMINATION PERCENTAGE (%):
The germination percentage was calculated three weeks after planting, and the trait was calculated using the following equation previously **(Elshookie & Cheyed , 2023)**.
GR = (Ng / Np) *100 ……… (5).
Since:
GR = Germination percentage (%).
Ng = Number of germinated seeds.
Np = Number of seeds planted.

RESULTS AND DISCUSSION

SOLAR PANEL POWER (watt).
Table (2) shows the effect of the solar panel type, the operating pressure, the dripper type, and their interactions on the solar panel power. The results clarify the effect of the solar panel type on the solar panel power. It was found that there is a significant effect of the type of panel on the solar panel power (watt), as the solar panel recorded the monocrystalline solar panel recorded the highest value for the average solar panel power, reaching (1191 watt), while the polycrystalline solar panel recorded the lowest value for the average solar panel power, reaching (1099 watt). The reason may be due to the specifications of the solar panel for the monocrystalline panel, which gave the highest power. The results also showed the effect of the type of operating pressure on the solar panel power (watt), achieved the highest average the solar panel power (1156 watts), while (P1) achieved the lowest average power of (1133 watt).

The results showed the effect of the dripper type on the studied characteristic (watt), the T2 dripper achieved the highest solar panel power of (1157 watt), while the T1 dripper achieved the lowest power of (1131 watt). The results showed that the effect of the two-way interaction between the solar panel type and the operating pressure on the solar panel power (watt), as the mono-crystalline solar panel with P2 was superior, recording the highest solar panel power of (1208 watt), while the poly-crystalline solar panel with P1 recorded the lowest. The solar panel power reached (1092 watt). The results show the effect of the two-way interaction between the solar panel type and the dripper type on the above characteristic, as the mono-crystalline solar panel with T3 recorded the highest the solar panel power, reaching (1204 watt), while the poly-crystalline solar panel with T1 had the lowest the solar panel power (1080 watt). The results showed the effect of the two-way interaction between the operating pressure and the dripper type on the solar panel power (watt). The results showed that P2 with T2 achieved the best power of the solar panel that reached (1163 watt), while. p1 with T1 had the lowest solar panel power, as it was recorded (1111 watt).

Table (2): The effect of the solar panel type, operating pressure, dripper type, and their interactions on the solar panel power (watt).

C * P		**(T) Dripper Type**			**Operating pressure (P)**	**Solar panel type (C)**
		T3	**T2**	**T1**		
1174		1190	1174	1158	P1	monocrystalline
1208		1217	1201	1205	P2	
1092		1084	1130	1064	P1	polycrystalline
1105		1096	1124	1095	P2	
N.S	LSD_{C*P}	N.S			LSD_{C*P*T}	
C * T						
panel type average		T3	T2	T1	Solar panel	
1191		1204	1187	1182	monocrystalline	
1099		1090	1127	1080	polycrystalline	
51.76	LSD_{C}	N.S			LSD_{C*T}	
P * T						
Pressure average		T3	T2	T1	operating pressure	
1133		1137	1152	1111	P1	
1156		1156	1163	1150	P2	
N.S	LSD_{P}	N.S			LSD_{P*T}	
T						
		T3	T2	T1	Dripper type	
		1147	1157	1131	Dripper type average	
		N.S			LSD_{T}	

ENERGY COST ($/KWh).

Table (3) elucidates the impact of the solar panel type, the operating pressure, the dripper type, and their interactions on energy costs ($/KWh). The results showed the effect of the solar panel type on energy costs ($/KWh) where the polycrystalline solar panel type achieved the highest average energy costs of (0.357 $/KWh) and the solar panel also achieved monocrystalline had the lowest average energy costs, reaching (0.230 $/KWh) and from the table we conclude that there is a significant difference between the solar panel type and the studied characteristic, and this is consistent with **(Al-Jumaili , 2023)**. The results showed the effect operating pressure on energy costs, where p1 gave the highest energy costs, reaching (0.297 $/KWh) while p2 recorded, the lowest energy costs amounted to (0.289 $/KWh). The results indicated that there is a significant difference between the dripper type on energy costs ($/KWh) as the results showed that the T1 dripper type achieved the highest energy costs amounting to (0.317 $/KWh) while the T3 dripper type achieved the lowest energy costs amounting to (0.278 $/KWh). The results indicated that the effect of the two-way interaction between the solar panel type and the operating pressure on energy costs ($/KWh) as it was found that the polycrystalline solar panel with p1 achieved the highest energy costs amounting to (0.359 $/KWh) while the monocrystalline solar panel with p2 achieved the lowest energy costs amounting to (0.224$/KWh). The results showed the effect of the two-way interaction between solar panel type and dripper type on energy costs ($/KWh) The highest energy costs were obtained with the polycrystalline solar panel with T1, where it was recorded (0.378 $/KWh) as it achieved the lowest energy costs with the monocrystalline solar panel with T2, which reached (0.211 $/KWh) The results showed the effect of the two-way interaction between the operating pressure and dripper type, as P1 and T1 achieved the highest energy costs (0.324$/KWh) while P1 and T3 recorded the lowest energy costs (0.276$/KWh). The table shows the effect of the three-way interaction between the solar panel type, operating pressure, and dripper type on energy costs ($/KWh), the polycrystalline solar panel with p1 and T1 recorded the highest energy costs (0.378$/KWh), while the monocrystalline solar panel with p2 and T2 recorded the lowest energy costs (0.203$/KWh).

Table (3): The effect of the solar panel type, the operating pressure, the dripper type, and their interactions on the energy costs ($/KWh).

<table>
<tr><th colspan="2" rowspan="2">C * P</th><th colspan="3">(T) Dripper Type</th><th rowspan="2">Operating pressure (P)</th><th rowspan="2">Solar panel type (C)</th></tr>
<tr><th>T3</th><th>T2</th><th>T1</th></tr>
<tr><td colspan="2">0.235</td><td>0.229</td><td>0.219</td><td>0.257</td><td>P1</td><td rowspan="2">monocrystalline</td></tr>
<tr><td colspan="2">0.224</td><td>0.213</td><td>0.203</td><td>0.257</td><td>P2</td></tr>
<tr><td colspan="2">0.359</td><td>0.322</td><td>0.363</td><td>0.391</td><td>P1</td><td rowspan="2">polycrystalline</td></tr>
<tr><td colspan="2">0.354</td><td>0.346</td><td>0.353</td><td>0.364</td><td>P2</td></tr>
<tr><td>N.S</td><td>LSD_{C*P}</td><td colspan="3">N.S</td><td colspan="2">LSD_{C*P*T}</td></tr>
<tr><td colspan="7">C * T</td></tr>
</table>

Panel type average		T3	T2	T1	Solar panel
0.230		0.221	0.211	0.257	monocrystalline
0.357		0.334	0.358	0.378	polycrystalline
0.025	LSD_C	N.S			LSD_{C*T}
P * T					
Pressure average		T3	T2	T1	operating pressure
0.297		0.276	0.291	0.324	P1
0.289		0.279	0.278	0.311	P2
N.S	LSD_P	N.S			LSD_{P*T}
T					
		T3	T2	T1	Dripper type
		0.278	0.285	0.317	Dripper type average
		0.023			LSD_T

IRRIGATION SYSTEM EFFICIENCY (%)

Table (4) shows the effect of solar panel type, operating pressure, dripper type and their interactions on the efficiency of the irrigation system (%). The results showed the effect of the type of solar panel on the efficiency of the irrigation system (%). The results indicated that there was a significant difference of the type of solar panel on the efficiency of the irrigation system (%), as the monocrystalline solar panel achieved the highest average irrigation system efficiency (%), achieving (84.22%). While the polycrystalline solar panel achieved the lowest average irrigation system efficiency (%), which was (82.63%). The results showed the effect of operational pressure on the irrigation system efficiency (%), as P2 achieved the highest average irrigation system efficiency (%), which was (83.86%). P1 recorded the lowest average irrigation system efficiency (%), reaching (82.99%), as there was a significant difference between the operating pressure on the irrigation system efficiency (%). The table showed the effect of the dripper type on the irrigation system efficiency (%), where there was a significant difference between dripper type and the studied characteristic (%), the T2 dripper recorded the highest irrigation system efficiency rate (%), reaching (84.42%), while the T1 dripper recorded the lowest irrigation system efficiency rate (%), which was (82.26%). The results also showed the effect of the two-way interaction between the solar panel type and the operating pressure on the efficiency of the irrigation system (%), where the monocrystalline solar panel with p2 achieved the highest value for irrigation system efficiency, amounting to (84.86%), and the polycrystalline solar panel with p1 achieved the lowest value for efficiency. The irrigation system reached (82.41%), and the results showed that there was a significant difference between the two-way interaction on the irrigation system efficiency (%). The results indicated the effect of the two-way interaction between the solar panel type and the dripper type on the irrigation system efficiency (%), as there was a significant difference between the solar panel type and the dripper type according to the studied characteristic (%), which gave the highest rate of irrigation system efficiency (%) for the monocrystalline solar panel with T2, which reached (85.57%), while it gave the lowest rate of irrigation system efficiency for the polycrystalline solar panel with T1, which reached (85.57%). 81.73%). The results indicated the effect of the two-way interaction between the operating pressure and the dripper type on the irrigation system efficiency (%), as they indicated a significant difference between the two-way interaction and the studied characteristic (%), as it was noted that P2 with T2 achieved the highest values for the irrigation system efficiency, amounting to (84.27). %) and P1 with T1 achieved the lowest values for the irrigation system efficiency, which was (81.71%). The results also indicated the effect of the three-way interaction between the solar panel type, the operating pressure, and dripper type on the irrigation system efficiency (%), as the highest values for the irrigation system efficiency were achieved. The monocrystalline solar panel with p2 and T2 was (86.32%), while the polycrystalline solar panel with p1 and T1 achieved the lowest irrigation system efficiency values (%).

Table (4): shows the effect of solar panel type, operating pressure, dripper type and their interactions on the efficiency of the irrigation system (%).

C * P		**(T) Dripper Type**			**Operating pressure(P)**	**Solar panel type (C)**
		T3	T2	T1		
83.57		83.87	84.82	82.01	P1	monocrystalline
84.86		84.72	86.32	83.54	P2	
82.41		82.89	82.93	81.40	P1	polycrystalline
82.85		82.87	83.61	82.07	P2	
0.38	LSD_{C*P}	N.S			LSD_{C*P*T}	
C * T						
Panel type average		T3	T2	T1	Solar panel	
84.22		84.30	85.57	82.78	monocrystalline	
82.63		82.88	83.27	81.73	polycrystalline	
0.43	LSD_{C}	0.41			LSD_{C*T}	
P * T						
Pressure average		T3	T2	T1	Operating pressure	
82.99		83.38	83.88	81.71	P1	
83.86		83.80	84.97	82.81	P2	
0.32	LSD_{P}	0.42			LSD_{P*T}	
T						
		T3	T2	T1	Dripper type	
		83.59	84.42	82.26	Dripper type average	
		0.3			LSD_{T}	

GERMINATION PERCENTAGE (%)

Table (5) shows the effect of the solar panel type, operating pressure, the dripper type, and their interactions on the germination percentage (%). The results showed the effect of the solar panel type on the germination percentage (%). The results indicated that there was a significant difference for the solar panel type on the germination percentage (%), where the monocrystalline solar panel type had the best average germination percentage (86.11%), while the solar panel type scored the polycrystalline solar panel had the lowest average germination percentage (79.86%) these results are consistent with (**Jassim & Zeinaldeen, 2023)**. The results showed the effect of operating pressure on the germination percentage (%). P2 recorded the best average germination percentage (83.68%), and P1 recorded the lowest average germination percentage (82.29%). The results indicate the effect of the dripper type used on the germination percentage (%), as it had a significant effect on the studied trait (%), as the T2 dripper type had the highest value for the germination percentage, which was (86.46%), while the T1 dripper type had the lowest value for which was (79.17%). The results indicate the effect of the two-way interaction between the solar panel type and the operating pressure on the germination percentage characteristic (%), as the monocrystalline solar panel with p2 achieved the highest value for the germination percentage, which was (86.81%), and the polycrystalline solar panel with p1 achieved the lowest value for the germination percentage characteristic (%) which was (79.17%). The results also showed the effect of the two-way interaction between the solar panel type and the dripper type on the germination percentage (%), as the highest rate of germination percentage was recorded for the monocrystalline solar panel with T2, reaching (92.71%), and the lowest rate of germination percentage was recorded for the polycrystalline solar panel. With T1, it was recorded (78.12%). As the results indicated the effect of the two-way interaction between the operating pressure and the dripper type on the germination percentage (%), where p2 with T2 achieved the highest value for the germination percentage, which was (88.54%), while p1 with T1 achieved the lowest. Average germination percentage (79.17%). The results also showed the effect of the three-way interaction between the solar panel type, the operating pressure, and the dripper type on the characteristic of the germination rate (%). The results showed that the monocrystalline solar panel, p2 and T2 achieved the highest value of the germination percentage, amounting to (95.83). %), as the polycrystalline solar panel, p1 and T1 achieved the lowest value for the germination percentage, which was (77.08%).

Table (5): shows the effect of the solar panel type, operating pressure, the dripper type, and their interactions on the germination percentage (%).

C * P		**(T) Dripper Type**			**Operating pressure(P)**	**Solar panel type (C)**
		T3	**T2**	**T1**		
85.42		85.42	89.58	81.25	P1	monocrystalline
86.81		85.42	95.83	79.17	P2	
79.17		81.25	79.17	77.08	P1	polycrystalline
80.56		81.25	81.25	79.17	P2	
N.S	LSD_{C*P}	N.S			LSD_{C*P*T}	
C * T						
Panel type average		T3	T2	T1	Solar panel	
86.11		85.42	92.71	80.21	monocrystalline	
79.86		81.25	80.21	78.12	polycrystalline	
LSD_C	2.658	LSD_{C*T}			LSD_{C*T}	
P * T						
Pressure average		T3	T2	T1	Operating pressure	
82.29		83.33	84.38	79.17	P1	
83.68		83.33	88.54	79.17	P2	
N.S	LSD_P	N.S			LSD_{P*T}	
T						
		T3	T2	T1	Dripper type	
		83.33	86.46	79.17	Dripper type average	
		2.016			LSD_T	

CONCLUSION:

We conclude that the three-way interaction of monocrystalline solar panels with P2 and T2 achieved the highest results in irrigation system efficiency (%) and germination percentage (%) with the lowest energy costs($/KWh).

REFERENCES

1. Abdullah, A., & Kadhim, Z. (2023). Minimization of water needs in iraqi agriculture in light of the prevailing cropping combination during. *Iraqi Journal of Agricultural Sciences, 54*(1), 189-204.
2. Ahmed, S. H. (2012). Effect of water stress and hill spacing on seed yield and some growth traits of sunflower. *The Iraqi Journal of Agricultural Sciences, 43*(4), 43-72.
3. Aldulaimy, S. E., Al-Mehmdy, S. M., & Aljanabi, M. A. (2018). Evaluation of used exudative irrigation tubes and drip irrigation for some soil water parameters and consumptive use of cucumber. *Iraqi Journal of Agricultural Sciences , 49*(5), 921-931.
4. Al-Jumaili , A. Q. (2023). *Effect of solar panel type and distances between sab-lines on the performance of different irrigation systems and Faba bean yield*. MSc Thesis. College of Agriculture Engineering Sciences, University of Baghdad, Iraq.
5. Al-Lami, A. A., Ati, A. S., & Al-Rawi, S. S. (2023). Determination of water consumption of potato under irrigation systems and irrigation intervals by using polymers and bio-fertilizers in desert soils. *Iraqi Journal of Agricultural Sciences, 54*(5), 1351-1363.
6. AL-Mhmdy, S. M., & AL-Dulaimy, S. E. (2018). Performance evaluation of drip irrigation system according to the suggested standards. *Iraqi Journal of Agricultural Sciences, 49*(6), 1099-1109.
7. Al-Taif, N. I., & Al-Hadithi, E. K. (1988). *Irrigation basics and applications.* University of Mosul,Republic of Iraq: Directorate of Book House for Printing and Publishing.
8. Başaran, K., Bozyiği, F., Siano, P., Taşer, P. Y., & Kılınç, D. (2020). Systematic literature review of photovoltaic output power forecasting. *IET Renewable Power Generation, 14*(19), 3961-3973.
9. Elshookie, M. M., & Cheyed , S. H. (2023). *Seed growth relationships*. Baghdad: House of books and documents in Baghdad.
10. Grant, F., Sheline, C., Sokol, J., Amrose, S., Brownell, E., Nangia, V., & Winter V, A. (2022). Creating a Solar-Powered Drip Irrigation Optimal Performance model (SDrOP) to lower the cost of drip irrigation systems for smallholder farmers. *Applied Energy,* 323(1), 119563.
11. Jassim, A. Q., & Zeinaldeen, L. A. (2023). The Effect of Solar Panel Type on some Irrigation System Parameters and Bean Crop Germination Percentage. *Earth and Environmental Science* (p. 012123). United Kingdom: IOP Publishing.
12. Khalaf, N. S., & Hassan, W. A. (2022). Study of yield and its components of introduced varieties of maize under different planting densities. *Iraqi Journal of Market Research and Consumer Protection, 14*(1), 52-64.
13. Khattab, E. A., & El-Housini, E. A. (2019). Evaluation of some lentil varieties under sprinkler and dripping irrigation systems in newly reclaimed sandy soil. *Iraqi Journal of Agricultural Sciences, 50*(3), 753-758.
14. Mahal, S. H., Al-Lami , A. M., & Mashee, F. K. (2022). Assessment of the impact of urbanization growth on the climate of baghdad province using remote sensing techniques. *Iraqi Journal of Agricultural Sciences , 53*(5), 1021-1034.

15. Manfaluthy, M., Pangestu, A., Arif , R., & Sanjaya, L. A. (2019). Watt Peak Meter of Solar Panel. *Journal of Physics: Conference Series*, 012097.
16. Maurya, V. N., Ogubazghi, G., Misra, B. P., Maurya, A. K., & Arora, D. K. (2015). Scope and review of photovoltaic solar water pumping system as a sustainable solution enhancing water use efficiency in irrigation. *American Journal of Biological and Environmental Statistics, 1*(1), 1-8.
17. Rasheed, Z. K. (2021). Modeling of subsurface horizontal porous pipe irrigation under different conditions. *Iraqi Journal of Agricultural Sciences, 52*(4), 949-959.
18. Sovacool, B. K. (2009). Rejecting renewables: The socio-technical impediments to renewable electricity in the United States. *Energy Policy, 37*(11), 4500-4517.
19. Tawfiq, A. A.-K. (2019). Effect of plant densities on the growth and yield of sunflower Helianthus annuusL. *Iraqi Journal of Market Research and Consumer Protection, 11*(2), 78-83.
20. Zeinaldeen, L. A. (2020). *Estimating the performance of hybrid (monocrystalline PV - cooling) system using different factors*. phD Thesis. Carbondale, Illinois, Southern University, United States of America,