Journal of Water Resources and Geosciences
Vol. 3, No. 2, 2024

The effect of the type of solar panels, irrigation systems, and distances between planting lines on the yield of beans (Vicia Faba…L)

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Abstract

This research is fulfilled in Al-Raed Research Station, that is situated on the main road of Baghdad-Anbar through conducting an experiment which was conducted during the winter season of 2022-2023 so as to determining the influence of the kind of solar panels, watering systems (irrigation), and distances between planting lines on the yield of beans (Vicia Faba… L). Three replications of a randomised complete block design (RCBD) were employed. There are three components to the experiment. The solar panel type—mono-crystalline and poly-crystalline—was the first factor. The drip and sprinkler irrigation system, which has two levels, was the second component. The distances (40, 60, and 80 cm) between the sub-lines with three levels constituted the third factor. The subsequent metrices were examined: solar panel efficiency (%), Amount of irrigation water used (m^3. season-1), Consistency coefficient (homogeneity) (%), Germination percentage (%), The outcomes indicate that monocrystalline solar panels fulfilled the best of these signs: efficiency of solar panel, consistency coefficient (homogeneity), and germination rate with the least amount of irrigation water used during the season (24.74%) (93.42%) (90.40%) (3.927 m^3. season-1), respectively. Additionally, the drip watering technique produced the best results for solar panel efficiency, consistency coefficient, and germination percentage, with the lowest amount of water for irrigation (22.23%) (92.93%) (95.90%) (3.00 m^3. season-1), to arrange. Furthermore, the distance (40 cm) achieved the ultimate values of coefficient of uniformity and the germination percentage with the least amount of irrigation water used during the season (92.05%) (95.10%) (3.05 m^3. season-1), respectively. Further research should explore the long-term impacts of integrating mono-crystalline solar panels with drip irrigation across various crops and environmental conditions.

Keywords: Type of solar panel, Irrigation system, Plant density, Germination percentage, Beans.

تأثير نوع من الألواح الشمسية وأنظمة الري والمسافات بين خطوط الزراعة على محصول الفول(Vicia Faba…L)

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الخلاصة

نفذت تجربة في محطة أبحاث الرائد الواقعة على طريق بغداد - الانبار. أجريت خلال الموسم الشتوي 2022-2023 بهدف معرفة تأثير نوع الألواح الشمسية وأنظمة الري والمسافات بين خطوط الزراعة في محصول الفول .(Vicia Faba…L) تم استخدام تصميم القطاعات العشوائية الكاملة (RCBD) بثلاثة مكررات. تتكون التجربة من ثلاثة عوامل. العامل الأول كان نوع الألواح الشمسية بمستويين: أحادية التبلور ومتعددة التبلور. العامل الثاني هو نظام الري بمستويين: نظام الري بالتنقيط والري بالرش. أما العامل الثالث فكان المسافات بين الخطوط الفرعية بثلاثة مستويات (40، 60، 80 سم). تمت دراسة المؤشرات التالية: كفاءة الألواح الشمسية (%)، كمية مياه الري المستخدمة (م^3. الموسم-1)، معامل التجانس (التجانس) (%)، نسبة الإنبات (%)، وأظهرت النتائج أن الألواح الشمسية أحادية البلورية حققت أفضل المؤشرات التالية: كفاءة الألواح الشمسية، معامل التماسك (التجانس)، ومعدل الإنبات مع أقل كمية من مياه الري المستخدمة خلال الموسم (24.74%) (93.42%) (90.40%) (3.927 م3. الموسم-1))، على التوالى. كما حقق نظام الري بالتنقيط أعلى القيم في كفاءة الألواح الشمسية ومعامل التماسك ونسبة الإنبات، مع أقل كمية مياه للري (22.23%) (92.93%) (95.90%) (3.00 م^3.موسم-1)، لترتيب. أظهرت النتائج أن المسافة (40 سم) حققت أعلى قيم معامل التجانس ونسبة الإنبات مع أقل كمية من مياه الري المستخدمة خلال الموسم (92.05%) (95.10%) (3.05 م^3 الموسم-1). على التوالى . توصي الدراسة بالتحري عن التاثيرات طويلة الأمد بخصوص دمج الالواح الشمسية أحادية البلورة مع نظام الري بالتنقيط على مختلف المحاصيل والظروف البيئية.

الكلمات المفتاحية: نوع اللوح الشمسي، نظام الري، كثافة النبات، نسبة الإنبات، الفول.

1. Introduction

The transformation of the energy system from the traditional one based on fossil fuels to renewable energy has become a necessary matter that all countries of the world are seeking, with the increasing costs of traditional sources and their monopoly by certain countries. With the growing phenomenon of global warming that has struck all countries of the world, affecting its water resources, and with the increase in population, we have begun to see that the changes have become a challenge to the sustainability of life on the surface of the Earth. Therefore, the importance of creating projects that integrate clean energy with modern irrigation systems that regulate water comes with a focus on exploiting a unit of area for agriculture (Al-Jumaili & Zeinaldeen, 2023). Vegetation cover is one of the most important factors in the rise in temperature of the city of Baghdad, with a difference of 6 degrees Celsius for the period from 2001 to 2020 as a result of urban encroachment on its vegetation cover, which clearly contributed to the growing phenomenon of global warming (Mahal ,et ,al., 2022) . The availability of two public kinds of solar panels available in the market, namely monocrystalline and polycrystalline types, causes confusion in choice to the point that many solar panel users wonder about the differences between solar panels through a study that showed the superiority of monocrystalline panels in production capacity (9.18%) over polycrystalline panels(Pratama & Watiasih, 2020). Using the right type of solar panels can create advantages through a study that showed that using monocrystalline solar panels was more efficient than polycrystalline solar panels(Jassim & Zeinaldeen, 2023). The quantity of solar radiation affects the functioning of solar panels and the sum of energy emitted that they collect per square meter (Zeinaldeen, 2020). Weather is among the elements influencing the effectiveness of a solar panel(Sugianto, 2020). Water-saving techniques such as drip and sprinkler irrigation will not individually lower the additional requirement for irrigation water, but will assist increase groundwater levels, but they require a regular energy supply(Dhiman, 2022). In recent years, the problem of water scarcity has gradually become a threat in many agricultural areas so it requires a well-planned irrigation system such as drip or sprinkler irrigation system which will be more beneficial to farmers (Yadahalli ,et ,al., 2020). With increasing concerns about the decline of water resources, it has become necessary to implement modern irrigation systems to conserve water, in line with sustainable agricultural practices (Masri ,et ,al., 2015).The sustainable agricultural development strategy depends on improving the use of water used for field irrigation with contemporary irrigation systems that are compatible with the goal of reducing water waste and improving the effective use of water (Awwad ,et, al., 2023). One may think of broad beans as a plant protein source. Beans can be used in many different culinary recipes and provide important micronutrients. Novel applications in the food companies involve plant-based meat replaces and fortified gluten free- fortified items, and food sources of ordinary colour, protein, and fibre. (Salvador-Reyes, et ,al., 2023). The food industry has become more concerned with the consumer in terms of health and the advantages of local beans in terms of low cost and their high nutritional content of protein and fiber, in addition to their benefits to the soil in which they are grown. We have begun to see a focus on them in recent years (Badjona ,et ,al., 2023). There is a slow shift from animal to vegetarian diet among consumers due to growing health concerns regarding animal food consumption, adverse health effects due to saturated fats coupled with proteins and worrying sustainability of the environmental obstacles. Acknowledging plant proteins, potential health advantages, Vicia faba, could be a suitable source of proteins for the human diet. Compared to other legumes, beans are nutritionally beneficial due to their high proportion of protein to carbohydrates and superior amino acid content, approximately 85% (Dangi ,et ,al., 2022). The impact of various kinds of nearby produced risers and various operating pressures on soil characteristics and maize production was explored in research conducted at Al-Raed Research Station. The study, led by (Abbas & Jasim, 2022) found that automatic risers significantly outperformed traditional risers in water usage efficiency, moisture distribution, and maize yield. Notably, the automatic external tube riser achieved a grain yield of 6.89 tons per hectare and exhibited the ultimate moisture uniformity at 85.35%. This underscores the benefits of using locally designed automatic risers in fixed sprinkler irrigation systems to enhance water use and crop productivity. Research conducted by (Ebrahim ,et ,al., 2023) at Al-Raed Research Station assessed quinoa productivity using various water sources. They found that fresh water irrigation led to the ultimate yield (935 kg/ha), while saline water produced the lowest yield (595 kg/ha). Their statistical analysis confirmed significant differences between the treatments. In an experiment led by (Luay et al., 2023) at Al-Raid Research Station, barley growth was tested using dairy wastewater, groundwater, and river water. The results showed that groundwater irrigation yielded the ultimate output (1920 kg/ha), while river water irrigation yielded the lowest (1310.7 kg/ha). The study also noted an increase in soil EC levels by the end of the season for all treatments. The aim of the study are the comparison the performance of two types of solar panels, comparison of modern irrigation systems (drip, spray) and comparison of the effect of the variation of distances among the sub-lines on the yield of the crop. Thus, finding the best combination among the kind of solar panel and the mechanism of irrigation and the best distance between the sab-lines on the productivity of the Faba bean crop.

1.1 Research problem

Due to the challenges faced by most parts of the world, including our dear country, from the threat to food security as a result of population increase and problems related to providing the necessary water for irrigation, in addition to the obstacles to providing the energy sources necessary for the operation of various irrigation systems, and what the world in general and our country Iraq in particular is experiencing from the greenhouse effect caused by the continuous and increasing use of fossil fuel derivatives as an energy source, the subject of research came up.

2. MATERIAIS AND METHODS:

At Al-Raed Research Station, an investigation (experiment) was conducted. It was conducted throughout 2022-2023 winter season so as to identify the impact of different solar panel and the type of watering mechanism (irrigation), and distances between planting lines on the yield of beans (Vicia Faba… L). Three replications of a randomized complete block design (RCBD) were employed. There are three components of the experiment were adopted; the type of solar panel with couple of levels mono-crystalline and poly-crystalline. The mechanism of irrigation which had a two-level watering mechanism (i.e. drip and sprinkler irrigation) was the second component. The spaces among the sublines which had three levels (40, 60 and 80 cm) were the third component. The following traits were investigated: the solar panel efficiency (%), Amount of irrigation water used (m^3. $season^{-1}$), Consistency coefficient of (homogeneity) (%), percentage of Germination (%). The experimental field work was prepared by a series of agricultural operations then it was inundated with water and let to dry entirely over the sequence of 20 days. Because of the density of the Jungles that the Experimental field suffers from. Once the ploughing procedure is finished, the ploughed soil was smoothed with a rotary plough before being employed with a levelling and adjustment machine. On May 9th, 2022, a number of samples were collected from the field and delivered to the "National Center for Water Resources Management's" laboratories for analyzing the soil and to ascertain the field's chemical and physical properties and indicated in Table (1). The bean crop was by hand sown with two seeds in each hole at a depth of 3-5 cm and a spacing of 25 cm between each hole was considered. Weeds were then pulled out both manually and chemically on October, 15th 2022.

Table (1): Physical, chemical and hydraulic properties of the soil before planting

Soil depth	Soil articulations g.kg^{-1} sand	silt	Clay	Soil textu	Field volumetri water content a 33 Kps (Cm^{3}Cm^{-3})	Volumetric wate content at 1500 Kps (Cm^{3}Cm^{-3})	PH	EC dS.m^{-1}	soil bulk density Mg.m^{-3}
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

2.1 Characters Studied

2.1.1 Efficiency of Solar Panel %

Using a clap meter to measure the voltage and direct current at the same moment (impthe solar radiation falling on a square metre (W/m2), the active area of solar panel's (Active Space), and the panel's efficiency values for each trial unit were calculated.

during the irrigation process adopting the proposed equation from (Halim ,et ,al., 2023)

$$\eta = \frac{Vmp \times Imp}{Sr \times A} \qquad (1)$$

Where,

Vmp = “is the voltage of the electricity produced“.

Imp = “is the electrical current produced by the solar PV panel“.

Sr = “is the power of the incident solar radiation (W/m2) “.

A = “is the Active Space of the solar cell“.

2.1.2 The amount of water used for irrigation (m3, season-1).

A flow meter was installed on the main line of each experimental unit to determine the entire quantity of irrigation water used for the experiment and based on the volumetric moisture content of the soil when 50% (Al-Mehamdy & Maloki, 2017) of the device's water run out, which is at the field capacity (46.53). The wilting point is (26), that is, at point (36.26) of the field capacity for each experimental unit.

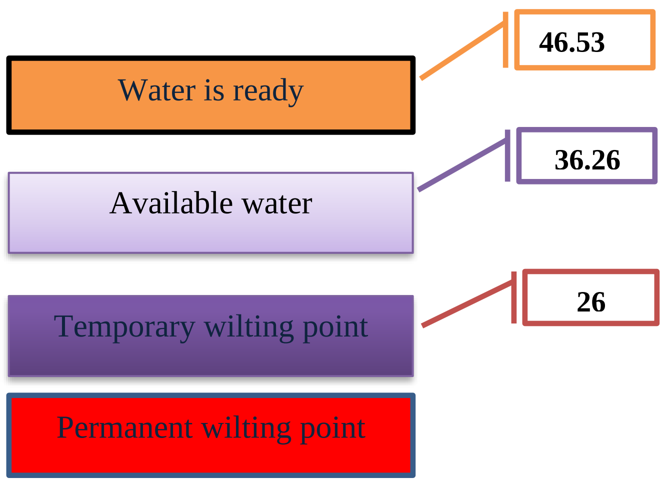

Figure (1): The field capacity chart shows the irrigation level of 50%.

2.1.3. Homogeneity Coefficient of (consistency).

The equation suggested by Analytics was applied to calculate the coefficient of homogeneity (Christiansen, 1942).

$$CU = 100\left(1 - \frac{\sum S}{M \times N}\right) \quad (2)$$

Where,

Cu = "homogeneity coefficient %".

S = "The amount of deviation in the values of individual observations from the average depths of the water obtained".

M = "mean of the observations".

N = "number of observations".

2.1.4. Germination percentage m^2.

Following fourteen days from the planting date, the percentage of germination was calculated using Walden's Equation (Al-Sahoki & Jiyad, 2023).

$$\mathscr{GP} = \left(\frac{ES}{TS}\right) \times 100 \qquad (3)$$

Since: -

$\mathscr{GP}$ = "germination rate m^2".

Es = "the number of seeds sprouting".

Ts = "total number of seeds sown".

3. Results and Discussion.

3.1. Solar Panel Efficiency %.

Table (2) displays the impact of solar panel type, the irrigation system, and the distances between the branch lines on the solar panel efficiency (%). The results of the effect of the type of solar panel indicate that the solar panel used with monocrystalline is superior to the solar panel used with polycrystalline in documenting the ultimate rate of efficiency (24.74). Whilst the second multi-crystalline type recorded an average efficiency of (19.05), which shows that there is a notable variation in the solar panel's efficiency depending on the type utilised, and these results are consistent with what was found by (Baghel & Chander, 2022). The reason may be that the manufacturing specifications for monocrystalline solar panels are higher than the manufacturing specifications for polycrystalline panels, which gives an advantage in giving greater capacity and thus higher efficiency to the monocrystalline panel.

The outcomes of the impact of the chosen irrigation system type demonstrated that the ultimate efficiency of the solar panel was recorded with the system of drip irrigation, reaching an average of (22.32), while the sprinkler irrigation system recorded the least average efficiency of (21.47).

The results demonstrates the impact of changing distances between the branch lines, as it was found that the ultimate average efficiency recorded for the solar panel was (22.37) at the distance (60 cm), while the least average efficiency recorded at the distance (40 cm) was (21.4).

The efficiency of the solar panel is a result of the reciprocal relationship between the type of panel and the irrigation system in use, as the monocrystalline solar panel with the drip irrigation system recorded the ultimate average efficiency of (25.40), while the polycrystalline solar panel with the sprinkler irrigation system recorded the least average efficiency of (18.84).

The results if the two-way relationship between the kind of solar panel and the distances between the sub-lines exhibited the efficiency of the solar panel, where the monocrystalline solar panel with a distance of (60 cm) obtained the optimal efficiency rate of (25.08), while the least efficiency rate was recorded with the polycrystalline solar panel at a distance of (40). cm) reached (as the results of the impact of the bilateral interaction among the type of irrigation system used and the distances between branch lines on the solar panel's efficiency indicated that the drip irrigation system documented at the distance (40 cm) the maximum rate of efficiency of (22.5), while the sprinkler irrigation system documented at the distance (40 cm). The least average efficiency was (20.3).

Table (2): The impact of the kind of solar panel, irrigation system, and distances between branch lines on the efficiency of the solar panel (%).

Type solar panel (C)	**Irrigation system (I)**	**Distances between sub-lines (D)**			**C * I**	
		40	**60**	**80**		
Polycrystalline	**Sprinkler**	17.87	19.83	18.83	18.84	
	Drip	19.31	19.47	18.98	19.25	
Monocrystalline	**Sprinkler**	22.73	25.00	24.55	24.09	
	Drip	25.69	25.17	25.33	25.40	
LSD C*I*D		2.941 N. S			**LSD C*I**	1.735
C * D						
Type solar panel (C)		**40**	**60**	**80**	**Average type solar panel**	
Polycrystalline		18.91	19.65	18.59	19.05	
Monocrystalline		24.21	25.08	24.94	24.74	
LSD C* D		1.956 N. S			LSD C	1.409 N. S
I * D						
Type of irrigation system (I)		**40**	**60**	**80**	**Average type irrigation system**	
Sprinkler		20.30	22.41	21.69	21.47	

Drip	22.50	22.32	22.15	22.32	
LSD I*D	2.244 N. S			LSD I	1.714N.S
D					
Distances between sub-lines (D)	40	60	80		
Average distances	21.40	22.37	21.92		
LSD D	1.60 N. S				

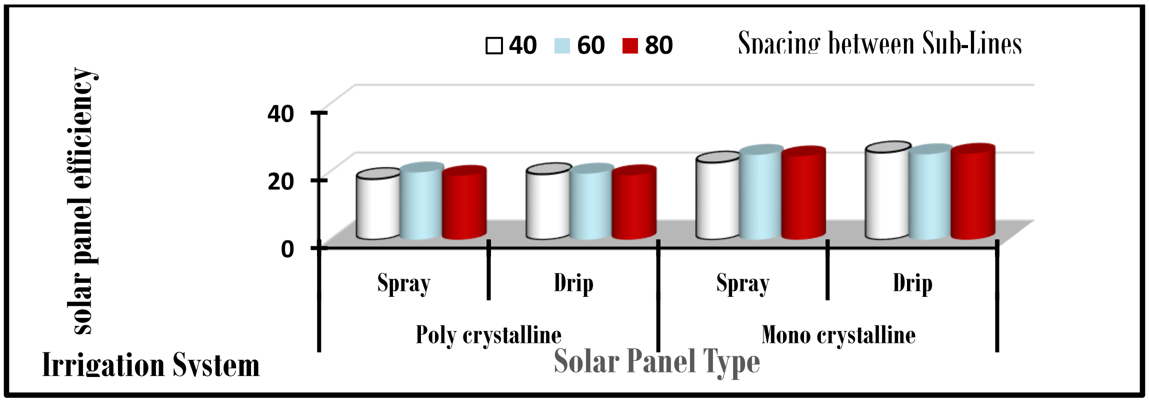

Figure (2): The impact of the kind of solar panel, irrigation system, and distances between branch lines on the solar panel's efficiency (%).

3.2. The amount of water used in irrigation is (m^3. Season^{-1})

Table (3) illustrates the impact of the kind of solar panel, irrigation system, and the distances between branch lines on the quantity of irrigation water utilized throughout the season (m^3, season^{-1}). It shows a noteworthy effect of the kind of solar panel on the character of the quantity of irrigation water used (m^3, season^{-1}). The polycrystalline solar panel documented the ultimate average values for the amount of irrigation water (m^3, season^{-1}), amounting to (4.29 m^3, season^{-1}), whereas the average values for the monocrystalline solar panel were the least for the amount of irrigation water (m^3, season-^{1}). was (3.927 m^3. Season^{-1}). The reason may be that the single-crystalline plate gives the water a higher compressive strength and greater stability in terms of weather variables, which allows for a good level of humidity that reduces the amount of water given between irrigation of the season, which is a positive characteristic and is one of the most important goals of the experiment.

The outcomes of the consequence of the form of irrigation system adopted on the quantity of irrigation water used (m^3, $season^{-1}$) showed us that there is a notable distinction in the sort of irrigation system applied on the quantity of irrigation water used (m^3, $season^{-1}$), as irrigation system with sprinklers documented the ultimate quantitative average values. Irrigation water (m^3, $season^{-1}$) in record (5,215 m^3, $season^{-1}$), whilst the irrigation system (drip) documented the low average values for the amount of irrigation water (m^3, $season^{-1}$), which was (3,001 m^3, $season^{-1}$).

The results show the impact of the distances between branch lines on the amount of irrigation water used (m^3, $season^{-1}$). There was a significant effect of the distances between branch lines on the amount of irrigation water applied within the period of the season (m^3, $season^{-1}$), as achieving the distance (80 cm) showed the ultimate average values for the amount of irrigation water used, which was (5.004 m^3, $season^{-1}$), while it was recorded Distance (40 cm). The least rates of irrigation water used amounted to (3.057 m^3. $Season^{-1}$). The reason may be due to the irrigation lines overlapping each other for a distance (40 cm), affecting a good moisture content, which reduces the amount of irrigation water given during the season.

The results of the binary interaction among the sort of solar panel used and the sort of the system specified for irrigation that is applied on the amount of irrigation water applied within the season (m^3. $season^{-1}$) show that there is a significant impact of the solar panel type used and the adopted type of irrigation system on the amount of irrigation water used (m^3. $season^{-1}$). Through the multi-crystalline solar panel with the sprinkler irrigation system achieving the ultimate average values of the amount of irrigation applied throughout the season (m^3. $Season^{-1}$) amounting to (5.503 m^3. $Season^{-1}$), while the mono-crystalline solar panel with the irrigation system recorded drip is the least rate of water given during the season, as it was (2.925 m^3. $Season^{-1}$).

The results of the binary interaction between the type of solar panel used and the spaces among sub-lines on the quantity of irrigation water applied throughout the season (m^3. $Season^{-1}$) also indicate that there is no noteworthy impact of the binary interaction between the type of solar panel used and the distances between sub-lines on the amount of irrigation water (m3, season-^{1}), as the polycrystalline solar panel with a distance of (80 cm) achieved the ultimate rates of irrigation water given during the season (m^3, $season^{-1}$), which was (5,203 m^3, $season^{-1}$), while we note that the solar panel achieved Single-crystalline with a distance of (40 cm), the least rates of water quantities given during the season were (2,870 m^3. $Season^{-1}$).

The two-sided relationship among the type of irrigation system used and the distances between branch lines also had a important effect on the quantity of irrigation water used during the season (m^3. $Season^{-1}$), through the sprinkler irrigation system at a distance of (80 cm) recording the ultimate rates of irrigation water quantity during the season amounting to (6,029 m^3. $Season^{-1}$), while the drip irrigation system at a distance of (40 cm) achieved the least value for averages of water quantity. Irrigation during the season amounted to (1,876 m^3, $season^{-1}$).

The results of the triple interaction between the type of solar panel used, the type of irrigation system used, and the distances between the branch lines on the amount of irrigation water used during the season (m^3. $Season^{-1}$), showed that there was a significant effect of the triple interaction between the solar panel type, the type of watering system (irrigation) being applied, and the distances between the lines. The sub-category on the quality of irrigation water used during the season, as the polycrystalline solar panel with the sprinkler irrigation system at a distance of (80 cm) achieved the ultimate average values for the amount of irrigation water during the season amounting to (6.251 m^3. $Season^{-1}$), while the mono solar panel recorded with the drip irrigation system at a distance of (40 cm), the lowest average amount of irrigation water given during the season reached (1,800 m^3, $season^{-1}$).

Table (3): Effect of the solar panel type, watering system, and distances between branch lines on the amount of irrigation water applied within the season (m^3. $Season^{-1}$)

Type solar panel (C)	**Irrigation system (I)**	**Distances between sub-lines (D)**			**C * I**	
		40	**60**	**80**		
Polycrystalline	**Sprinkler**	4.535	5.722	6.251	5.503	
	Drip	1.952	3.127	4.154	3.078	
Monocrystalline	**Sprinkler**	3.940	5.037	5.807	4.928	
	Drip	1.800	3.170	3.806	2.925	
LSD $_{C*I*D}$		0.1747			**LSD $_{C*I}$**	0.15
C * D						
Type solar panel (C)		**40**	**60**	**80**	**Average type solar panel**	
Polycrystalline		3.243	4.424	5.203	4.290	
Monocrystalline		2.870	4.103	4.806	3.927	
LSD C* D		0.1456 N. S			**LSD $_C$**	0.1893
I * D						

Type of irrigation system (I)	40	60	80	Average type irrigation system	
Sprinkler	4.237	5.379	6.029	5.215	
Drip	1.876	3.148	3.980	3.001	
LSD $_{I*D}$	0.1158			LSD $_{I}$	0..959
D					
Distances between sub-lines (D)	40	60	80		
Average distances	3.057	4.264	5.004		
LSD $_{D}$	0.0776				

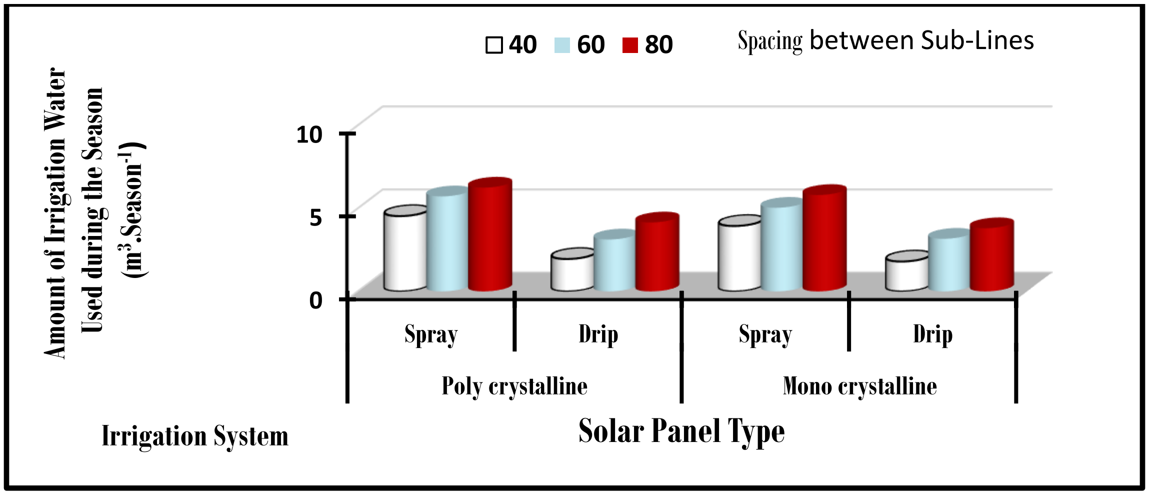

Figure (3): The Impact of solar panel applied, watering system, and spaces between branch lines on the amount of irrigation water applied throughout the season (m^3. $Season^{-1}$)

3.3. Coefficient of Consistency (Homogeneity).

Table (4) presents the impact of the solar panel type, the watering system, and the distances between the sub-lines on the homogeneity coefficient %. The results of the effect of the sort of solar panel adopted on the homogeneity coefficient (consistency) show the researchers that the monocrystalline solar panel had an important impact on the value of the coefficient Homogeneity (consistency): The monocrystalline panel showed the ultimate value for the average homogeneity coefficient, amounting to (93.42), whilst the polycrystalline solar panel recorded the lowest value for the average homogeneity coefficient, amounting to (87.72.The reason may be due to the stability of the power generated by the monocrystalline plate, leading to stability in the pump pressure and discharge, which has a positive effect on the studied characteristic.

The outcomes of the effect of the type of watering system used on the homogeneity coefficient (consistency) indicate that the drip watering system had an important impact on the value of the homogeneity coefficient (consistency), as the averages of the drip watering system recorded the ultimate value of the homogeneity coefficient averages, amounting to (92.42), while the averages of the sprinkler watering system recorded The lowest average value of the homogeneity coefficient is (88.20). The reason may be that the sprinkler watering system is affected by several factors, such as pressure fluctuations resulting from the power source being affected by the amount of solar radiation and the weather conditions surrounding the experiment.

The results of the effect of the distances between the sub-lines on the homogeneity coefficient (consistency) appear to us, as it is noted that the distances between the sub-lines had an important weight on the value of the homogeneity coefficient (consistency), as the average distances documented the ultimate value for the homogeneity coefficient (consistency) when the distance (40 cm) reached (92.05), while the average distances between the sub-lines recorded the lowest value for the homogeneity coefficient (consistency), reaching (89.26) with the distance (80 cm).

The results of the bilateral interaction among the solar panel type and the type of watering system adopted in terms of the homogeneity coefficient indicate to us that the bilateral interaction had an important weight on the value of the average homogeneity coefficient, as the monocrystalline solar panel with the drip watering system achieved the ultimate value for the average homogeneity coefficient (consistency). It reached (93.72), while the polycrystalline board with the sprinkler watering system documented the lowest average value of the homogeneity coefficient (consistency) which was (83.29). The reason may be that the efficiency of the monocrystalline plate is higher than that of the polycrystalline plate, which affects the power supply data.

The results of the bilateral interaction among solar panel type and the inter-distances between the sub-lines on the homogeneity coefficient (consistency) show that the dual interaction between the type of solar panel and the distances between the sub-lines did not have an important effect on the studied characteristic, as the mono-crystalline solar panel with the distance (40 cm) recorded the ultimate The average value of the homogeneity coefficient was (94.54), while the polycrystalline solar panel with a distance of (80 cm) recorded the lowest average value of the homogeneity coefficient (consistency), which was (86.58).

The results of the bilateral interaction between the type of watering system used and the distances between the branch lines on the coefficient of homogeneity (consistency) also indicate to us that the bilateral interaction between the watering system used and the distances between the branch lines has a significant effect on the character of the coefficient of homogeneity (consistency), as it is noted that the drip watering system registers with the distance (40 cm) The ultimate value of the average homogeneity coefficient (consistency) was (96.14), while the lowest value recorded for the average homogeneity coefficient (consistency) with the sprinkler watering system at the distance (80 cm) was (87.30). The reason may be that the drip watering system is a low-pressure system, so it is less affected by pressure variables.

The results of the triple interaction between the adopted solar panel type, the type of watering system used, and the distances between the branch lines on the character of the homogeneity coefficient show that there is meaningless effect. The triple interaction between the type of panel used, the type of watering system used, and the distances between the branch lines has a significant effect on the investigated characteristic, and it becomes clear that the solar panel used has achieved The monocrystalline solar panel with a drip watering system at a distance of (40cm) achieved the ultimate average value of the homogeneity coefficient, which was (96.72), while the polycrystalline solar panel with a sprinkler watering system at a distance of (80cm) achieved the lowest average value of the homogeneity coefficient, which was (82.44).

Table (4): The impact of solar panel type, watering system, and distances between branch lines on the homogeneity coefficient (consistency) %

Type solar panel (C)	**Irrigation system (I)**	**Distances between sub-lines (D)**			**C * I**	
		40	**60**	**80**		
Polycrystalline	**Sprinkler**	83.55	83.88	82.44	83.29	
	Drip	95.55	90.15	90.73	92.14	
Monocrystalline	**Sprinkler**	92.36	94.83	92.15	93.11	
	Drip	96.72	92.71	91.74	93.72	
LSD $_{C*I*D}$		2.845 N. S			**LSD $_{C*I}$**	2.186
C * D						
Type solar panel (C)		**40**	**60**	**80**	**Average type solar panel**	
Polycrystalline		89.55	87.02	86.58	87.72	

Monocrystalline	94.54	93.77	91.94	93.42	
LSD C* D	2.224 $^{N.S}$			**LSD $_C$**	2.738
I * D					
Type of irrigation system (I)	**40**	**60**	**80**	**Average type irrigation system**	
Sprinkler	87.95	89.36	87.30	88.20	
Drip	96.14	91.43	91.23	92.93	
LSD $_{I*D}$	1.950			**LSD $_I$**	1.493
D					
Distances between sub-lines (D)	**40**	**60**	**80**		
Average distances	92.05	90.39	89.26		
LSD $_D$	1.388				

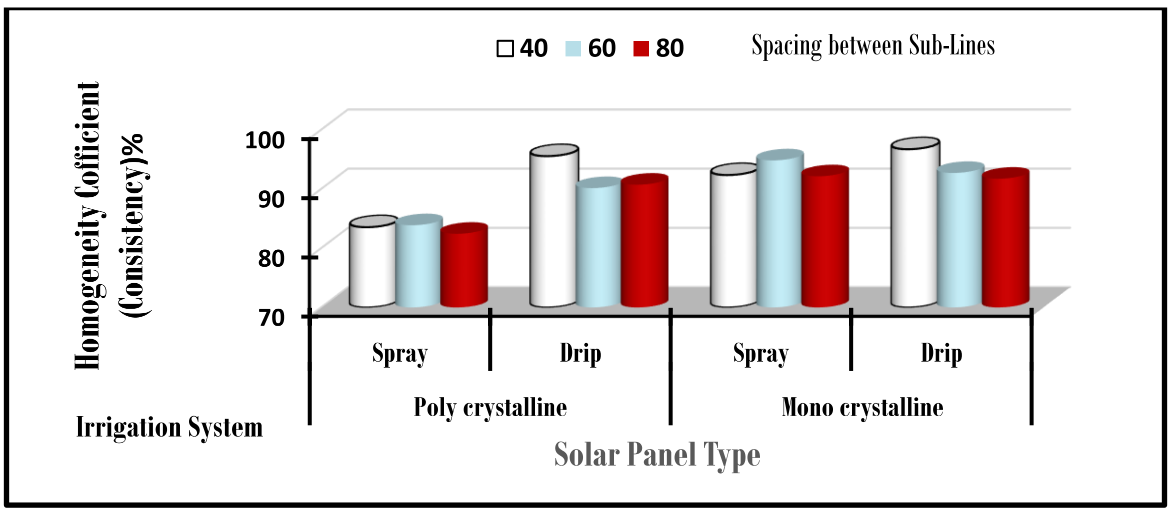

Figure (4): The impact of solar panel type, watering system, and distances between branch lines on the homogeneity coefficient (consistency) %

3.4. Germination Percentage

Table (5) presents the impact of solar panel type, watering system, and distances between branch lines on the germination rate (%). The results of the effect of the type of solar panel on the germination rate (%) show that there is no significant effect of the type of solar panel used in Germination rate (%). The monocrystalline solar panel recorded the ultimate average value of germination percentage, which was (90.40), while the polycrystalline solar panel recorded the lowest value of average germination percentage, which was (89.50).

The results of the impact of the watering system adopted on the germination rate (%) indicate that there is an important impact on the watering system adopted on the character of the germination rate (%), as the drip watering system showed the ultimate average value for the germination rate reaching (95.90), while the sprinkler watering system achieved the lowest. The average value of germination percentage was (84.00). The reason may be that dripper irrigation is close to the planted seeds, which contributes to achieving a stable moisture content of the seed, unlike sprinklers, which are affected by weather factors such as wind and temperature, thereby affecting the stability of the seed’s moisture.

The results of the impact of the spaces among the branch lines on the germination rate (%) imply that there is no significant effect of the distances between the branch lines on the germination rate (%), as the distance (40 cm) outperformed in achieving the ultimate average values of the germination rate, reaching (95.10), while the distance achieved (80 cm) The lowest value for the average germination percentage was (85.50). The reason may be due to the convergence of irrigation lines, which leads to increased interference in the moisture and stability of agricultural lines.

The results of the impact of the two-sided interaction between the type of solar panel and the type of watering irrigation system adopted on the germination rate (%) show that the two-sided interaction between the kind of solar panel applied and the type of watering system did not have an important effect on the germination rate, as the monocrystalline solar panel with the drip watering system achieved the ultimate value. The average germination percentage reached (96.20), while the polycrystalline solar panel with the sprinkler watering system recorded the lowest value for the average germination percentage at (83.30).

The results of the effect of the double interference between the type of solar panel and the distances between the sub-lines on the germination rate (%) showed that the double interference did not have a significant effect on the germination rate (%), as the single-crystalline solar panel recorded at the distance (40 cm) the ultimate value for the average percentage. Germination reached (95.80), while the polycrystalline solar panel with a distance of (80 cm) recorded the lowest value for the average germination percentage, reaching (82.60).

The results of the effect of the bilateral interaction between the type of watering system and the distances between the branch lines on the germination rate (%) show that the bilateral interaction did not have a significant effect on the studied trait, as the drip irrigation system at the distance (40 cm) achieved the ultimate average germination percentage, reaching (98.60). While the sprinkler watering system at a distance of (80 cm) recorded the lowest germination rates (77.10).

The results showed the effect of the three-way interaction between the type of solar panel, the type of watering system used, and the distances between the sub-lines on the germination rate. The three-way interaction between the type of panel, the type of watering system, and the distances between the sub-lines did not have a significant effect on the germination rate. The monocrystalline solar panel recorded with... The drip watering system at a distance of (40 cm) recorded the ultimate average value of germination percentage (%), which was (100.0), while the polycrystalline solar panel with a sprinkler watering system at a distance of (80 cm) recorded the lowest value of average germination percentage of (70.80). The reason may be due to the stability of the watering system of the monocrystalline plate, in addition to the fact that the drip watering system prepares water for the seed near it, which gives the seed a higher advantage in absorbing the water it needs, with the advantage of overlapping humidity at a distance (40 cm).

Table (5): The impact of the solar panel type, watering system, and distances between branch lines on the germination Percentage (%)

Type solar panel (C)	Irrigation system (I)	Distances between sub-lines (D)			C * I	
		40	60	80		
Polycrystalline	Sprinkler	91.70	87.50	70.80	83.30	
	Drip	97.20	95.30	94.40	95.60	
Monocrystalline	Sprinkler	91.70	79.20	83.30	84.70	
	Drip	100.0	95.10	93.40	96.20	
LSD $_{C*I*D}$		N. S			LSD $_{C*I}$	N.S
C * D						
Type solar panel (C)		40	60	80	Average type solar panel	
Polycrystalline		94.40	91.40	82.60	89.50	
Monocrystalline		95.80	87.10	88.40	90.40	
LSD C* D		N. S			LSD $_C$	N. S

I * D					
Type of irrigation system (I)	**40**	**60**	**80**	**Average type irrigation system**	
Sprinkler	91.70	83.30	77.10	84.00	
Drip	98.60	95.20	93.90	95.90	
LSD $_{I*D}$	N. S			**LSD $_{I}$**	10.26
D					
Distances between sub-lines (D)	**40**	**60**	**80**		
Average distances	95.10	89.30	85.50		
LSD $_{D}$	N. S				

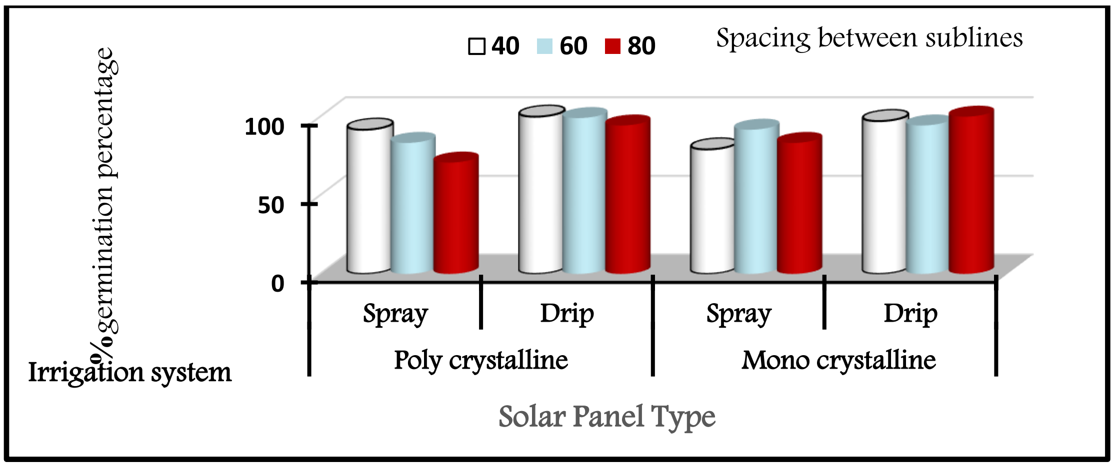

Figure (5): impact of the type of solar panel, watering system, and distances between branch lines on the germination Percentage (%)

4. Conclusion and Recommendations

Based on the results presented earlier, the followings were concluded:

Mono-crystalline solar panels achieved the ultimate average efficiency of (24.21%). The drip watering system is considered more efficient than the sprinkler watering system, as it achieves the ultimate irrigation uniformity with the least amount of irrigation water used during a consecutive season (96.72%) (1,800 m3. season). The Mono-crystalline solar panel with the drip watering system achieved the ultimate germination Percentage is (100%). Based on the findings of this study, it is recommended to utilize mono-crystalline solar panels in agricultural projects due to their superior efficiency and performance. Additionally, adopting drip watering systems is advised as they demonstrate better water use efficiency and uniformity compared to sprinkler systems. For optimal results in cultivating crops like faba beans, maintaining a planting line distance of 40 cm is suggested as it ensures higher uniformity and germination rates while minimizing water usage. Further research should explore the long-term impacts of integrating mono-crystalline solar panels with drip irrigation across various crops and environmental conditions. Policymakers are encouraged to support farmers through incentives for the adoption of these advanced irrigation and energy technologies, promoting sustainable agricultural practices and enhancing crop yields.

Reference

Abbas, K.I. and Jasim, A.A., 2022. Effect of Locally Made Riser Type and Operating Pressures of the Fixed Sprinkler Irrigation System on Some Soil Characteristics and Maize Yields. *NeuroQuantology*, *20*(4), p.32.

Al-Jumaili, A. Q. J., & Zeinaldeen, L. A. (2023). Effect of solar panel type and distances between sab-lines on of the performance of different irrigation systems and Faba bean. *College of Agricultural engineering sciences / University of Baghdad*.

Al-Mehamdy, S. M. H., & Maloki, M. M. (2017). The Effect of water depths and moisture depletion on vertical and horizontal distribution for moisture in soil profile under surface drip irrigation system. *Anbar Journal of Agricultural Sciences*, 15(1992–7479), 379–390.

Al-Sahoki, M., & Jiyad, S. H. (2023). Seed growth relationships. *House of books and documents in Baghdad*.

Awwad, A., Shalabi, K., Mubarak, O., & El-Sassy, W. (2023). Effect of Irrigation Scheduling under surface and Sub-Surface localized Irrigation Systems on bean Productivity. *International Journal of Advanced Research*, 11(12), 22–33. https://doi.org/10.21474/IJAR01/17953

Badjona, A., Bradshaw, R., Millman, C., Howarth, M., & Dubey, B. (2023). Faba Bean Processing: Thermal and Non-Thermal Processing on Chemical, Antinutritional Factors, and Pharmacological Properties. In Molecules (Vol. 28, Issue 14). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/molecules28145431

Christiansen, J. E. (1942). Irrigation by sprinkling (Berkeley, Ed.; Vol. 4). University of California.

Dangi, P., Chaudhary, N., Paul, A., Prabha, S., Kumar, R., & Paonia, A. (2022). Faba Bean Proteins: Extraction Methods, Properties and Applications. In Faba Bean: Chemistry, Properties and Functionality (pp. 245–273). Springer International Publishing. https://doi.org/10.1007/978-3-031-14587-2_10

Dhiman, M. (2022). Prominence and Visions of Drip and Sprinkler Irrigation System in Punjab Agriculture. https://www.researchgate.net/publication/360411517

Ebrahim, O.N., Abbas, K.I., Dawood, I.A. and Salim, A.H., 2023. The Role of Soil and Water Salinity Management on Quinoa Crop Productivity. *Journal of Water Resources and Geosciences*, *2*(2), pp.16-27.

Halim, L., Gun, S. E., & Wahab, F. (2023). Solar Panel Efficiency Improvement through Dual-Axis Solar Tracking with Fuzzy Logic and Water Treatment Techniques. Journal Nasional Teknik Electro, 20–29. https://doi.org/10.25077/jnte.v12n3.1120.2023

Jassim, A. Q., & Zeinaldeen, L. A. (2023). The Effect of Solar Panel Type on some Irrigation System Parameters and Bean Crop Germination Percentage. IOP Conference Series: Earth and Environmental Science, 1259(1). https://doi.org/10.1088/1755-1315/1259/1/012123

Luay, S., Ibrahim, K., Dawood, I.A. and Salim, A.H., 2023. Evaluation of Performance Barley Cultivation Using Different Types of Water Sources. *Journal of Water Resources and Geosciences*, *2*(2), pp.146-158.

Mahal, S. H., Al-Lami, A. M., & Mashie, F. K. (2022). Evaluating the impact of urban growth on the climate of Baghdad Governorate using remote sensing techniques. Iraqi Journal of Agricultural Sciences, 53(5), 1021–1034.

Masri, M., Ramadan, B., & El-Kady, M. S. (2015). Effect of water stress and fertilization on yield and quality of sugar beet under drip and sprinkler irrigation systems in sandy soil. International Scholars, 3 (5) (2167–0447), 414–425. https://doi.org/10.13140/RG.2.2.17749.27360

Pratama, E., & Watiasih, R. (2020). Perbandingan Performa Solar Panel Monocrystalline dan Polycrystalline.

Salvador-Reyes, R., Furlan, L. C., Martínez-Villaluenga, C., Dala-Paula, B. M., & Clerici, M. T. P. S. (2023). From ancient crop to modern superfood: Exploring the history, diversity, characteristics, technological applications, and culinary uses of Peruvian fava beans. In Food Research International (Vol. 173). Elsevier Ltd. https://doi.org/10.1016/j.foodres.2023.113394

Sugianto, S. (2020). Comparative Analysis of Solar Cell Efficiency between Monocrystalline and Polycrystalline. INTEK: Journal Panellation, 7(2), 92. https://doi.org/10.31963/intek.v7i2.2625

Yadahalli, M., Nayak, S. G., Hosamani, A., Pujari, S., & Herkal, P. (2020). Comparative Analysis of Sprinkler Irrigation System with Drip Irrigation System through IOT Module. International Journal of Advanced Research in Science, Engineering and Technology, 7. https://www.researchgate.net/publication/373391636

Zeinaldeen, L. A. (2020). Estimating the performance of hybrid (mono-crystallin PV-cooling) system using different factors [Solar panels]. Southern Illinois University.