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Evaluation of drip irrigation system performance using two solar systems under different tillage systems

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Abstract

This study was conducted at the Al-Raed Research Station – National Center, Ministry of Water Resources, to evaluate two solar energy systems (fixed and trackable solar panels) and their impact on the performance of the Gr drip irrigation system as well as their reflection on water consumption and sorghum yield under different soil tillage systems. A randomized complete block with a split plot design with four replications was adopted. The results showed that the tracking solar system outperformed the fixed system, achieving the lowest the energy consumption (1.07) kW/h, lowest water consumption was (19.79) m³/season and the highest for sorghum yield Average (2986) kg/ha. Soil tillage systems with spik-tooth harrows achieved the lowest average bulk density (1.02) g/cm³ and the highest Average sorghum yield (2949) kg/ha. The results indicated that the trackable solar panels is a more efficient option for the sustainability of agricultural resources, as they contribute to reducing energy and water consumption, and adopting appropriate soil tillage systems.

Keywords: **solar panel system, energy consumption, soil tillage systems, sorghum productivity, drip irrigation.**

Introduction

As a result of the excessive reliance on conventional energy sources, most of the world countries have started to face environmental challenges, Renewable energy has become one of the sustainable solutions that aim to achieve a balance between economic growth and environmental preservation. Among the most prominent renewable energy references is solar energy, which is characterized by its wide availability throughout the year, in addition to its role in reducing carbon emissions and its negative environmental impact [1]. Solar energy relies on exploiting the sun's rays and converting them into electrical energy using various technologies. The most important of them are solar panels, which are an essential part of solar energy systems used in many agricultural, industrial, and residential applications [2]. Solar panel systems are divided into two main types: Fixed and trackable solar panels. Fixed panels are fixed in one place at a specific angle of inclination to receive sunlight and are characterized by their low cost and ease of installation, but their efficiency is affected by the angle of incidence of sunlight during daylight hours [3].Trackable panels are characterized by their ability to follow the sun throughout the day, which increases the efficiency of exploiting solar radiation, ensuring that the maximum amount of energy is obtained, which is an important advantage in improving the productivity of solar energy [4].

Soil tillage is an important factor in optimizing agricultural processes and increasing productivity. These systems are used to improve soil structure and facilitate irrigation and aeration, thereby enhancing water and energy efficiency [5]. There are many types of soil tillage systems and equipment used [6]. Much equipment was used in the experiment which include spik-tooth harrows that are highly efficient in breaking up large masses of soil, which improves water permeability and reduces bulk density [7]. Rotary harrows, which work in a rotating motion, help break up the soil and remove weeds, making them suitable for spik or dense soils [8]. Disc harrows have also been used to prepare heavy soil, further improving their physical and chemical properties [9].

Research also studies of some important properties that directly affect the efficient use of agricultural resources and crop productivity. The energy consumed represents the total electrical energy or fossil fuels consumed in conducting agricultural operations and operating the necessary equipment, Energy consumption is considered an indicator of the system's efficiency and improving its performance. Previous studies have shown that trackable solar panels are more efficient in terms of energy consumption compared to fixed systems, as they make better use of solar radiation throughout the day [10]. The amount of water consumed, which is calculated as the total water used for irrigation during the agricultural season, is a crucial indicator to evaluate the efficiency of different irrigation systems under the influence of the type of solar energy system. Research shows that a trackable system minimizes water losses compared to a fixed system, making it a more sustainable option and the study of [11] asserted that the type of drip and water pressure directly affect the amount of water consumed [12]. Soil bulk density is a characteristic that expresses the hardness of the soil and the influence of soil tillage systems. Bulk density affects the water and air permeability of the soil, and consequently root growth and crop productivity. The effect of different types of harrows (solid, rotary, and disc harrows) on improving this property has been evaluated by [6] and a study by (Abdeljaleel and Zeinaldeen, 2024) showed that using appropriate tillage systems and equipment helps to reduce soil bulk density, especially with deep tillage. Finally, sorghum yield is the final objective to evaluate the performance of the studied systems. Productivity was measured by the weight of grains produced per unit area (kg/ha). This indicator is related to the efficiency of solar energy and soil tillage systems in improving agronomic conditions and enhancing production [13].

In this study, the impact of two types of solar energy systems (fixed and trackable) on the operation of drip irrigation systems was investigated, in addition to evaluating the impact of different soil tillage systems on energy and water consumption and sorghum yield. This study aims to evaluate the performance of drip irrigation systems powered by two solar energy configurations under different tillage practices, thereby enhancing resource-use efficiency in agriculture and promoting sustainable development through advanced technologies.

Materials and methods

The experiment was carried out in one of the fields belong to Al-Raid Research Station - National Centre located in the Aqar-quf area on the Baghdad-Anbar highway, at longitude 44.05 E, latitude 33.25 N and altitude 34.1 m above sea level during Spring season of (2024) in a soil with silty clay loam texture and some of its chemical and physical characteristics are shown in (Table 1).

Table 1. Some chemical and physical characteristics of the soil used in the research.

Soil Depth (cm)	Soil Aggregates (g.kg)			Soil Texture	Bulk Density (g/m³)	EC (dS/m)	pH	Volumetric Moisture Content at Wilting Point	Field Capacity (%)	Soil Penetration Resistance (kg/cm²)
	Sand	Silt	Clay							
0–30	130	520	330	silty Clay loam	1.37	8.13	7.7	20.57	44.54	1.11

Two types of solar energy systems were used: a trackable system that was manufactured locally, which works to track the sun's rays to improve the efficiency and the energy produced from the solar panels, and a fixed system to operate the drip irrigation system using Gr-type branch pipes to irrigate the sorghum crop The field was prepared for cultivation using different soil tillage systems (ploughing and Harrowing). The field was divided according to the design used to carry out the experiment, the length of the treatment was 20 m long and 3 m wide, 10 m distance was left before each treatment in order to stabilize the speed of the machinery unit. The experiment used a split-plot with a completely randomized block design with four replicates, the research included two factors: The first factor is the type of solar energy system, was representing the main plots with two levels: trackable and fixed solar system, the sub plots was tillage system with three levels: 1st moldboard plow with spik-tooth harrow, 2nd level mold board plow with rotary harrow and 3nd level moldboard plow with disc harrow. The whole experiment was conducted using the Gr drip irrigation system. The data obtained were collected and analyzed according to the experimental design by GenStat and the differences between the treatments were tested using least significant difference probability level, i.e. 0.05 L.S.D. The following characteristics were studied.

Pump energy consumption

It is measured according to the equation proposed by [14]:

$$E = Power * Time / 1000 \quad (1)$$

Where E = electrical energy of the solar panels (KW/ h), P = electrical power consumed (W), T= duration of the irrigation process (hours)

Bulk density

It is calculated according to the following equation [15]:

$$\rho_b = M_S / V_{Tot} \quad (2)$$

Where ρ_b = bulk density of the soil (g/cm³), M_S = dry mass of the soil (g), V_{Tot} = total volume of the soil (cm³)

Quantity of water consumed

The total amount of irrigation water for the experiment is measured by placing a flow meter on the main line of each experimental unit, based on the volumetric moisture content of the soil when 50% of the ready water is depleted, which is between the field capacity and the wilting point followed by [16][17].

Crop yield

Extracting the plant yield rate by taking ten plants randomly for each experimental unit and weighing the seeds multiplied by the plant density and expressed in units of kg/ha [18].

Results and Discussion

Pump energy consumption

Table 2 shows the effect of trackable and fixed system type on energy consumption by the pump (kW/h). The results show a significant effect between the two systems, as the trackable system achieved the lowest energy consumption during the season (1.07) kW/h, While the fixed system achieved the highest energy consumption during the season at (1.33) kW/h. The reason for that maybe related to improving of the efficiency for the solar panel by tracking the sun's rays throughout the day and obtaining the maximum amount of energy gained, which leads to produce of higher energy continuously, which in turn leads to the flow of water from the solar pump continuously, which works to add the required amount of water to the plant with less energy consumption and time during the irrigation process during the season [19].

Table 2. Effect of solar energy System on pump Energy Consumption (kW/h).

Solar Energy System Type	Pump Energy consumption
Tracking System	1.07
Fixed System	1.33
LSD0.05	0.036

The amount of water consumption

Table 3 shows the effect of solar energy system type and soil tillage systems and their interaction on the amount of water consumption during season (m^3/season). The results show that the type of solar energy system has a significant effect as it achieved the lowest Average of water consumption during season with the trackable system and reached (19.79) m^3/season, while the highest Average of the amount of water consumption during season with the fixed system reached (19.97) m^3/season. The results show that the type of solar energy system has a significant effect on the amount of water consumption during season with the fixed system (19.97) m^3/season. This effect is attributed to the efficiency of trackable systems in optimizing the angle of solar radiation received throughout the day, which leads to a reduction in the energy consumption required to operate the irrigation systems, thus reducing the amount of water consumption compared to fixed systems [19].

The results show that the soil tillage systems have a significant effect on the amount of water consumption during season (m^3/season). Mold board plow with spik-tooth harrows achieved the lowest Average of water consumption during season (19.76) m^3/season, while mold board plow with rotary harrows achieved the highest Average (19.98) m^3/season. That may be related to the different characteristics of the soil after tillage, as the method of soil tillage affects the porosity of the soil and the speed of water absorption, which reflects on the efficiency of its use and minimizing water loss [20].

The results showed that the two-way interaction between the solar energy system type and soil tillage systems had a non-significant effect on the amount of water consumption during season (m^3/season), whereas the trackable system and mold board plow with spik-tooth harrows achieved the lowest amount of water consumption during season (19.69) m^3/season, while the fixed system and mold board plow with rotating harrows achieved the highest amount of water consumption during season (20.06) m^3/season. While the fixed system and mold board plow with rotary harrows achieved the highest Average of the amount of water consumption during season and reached (20.06) m^3/seas

on.

Table 3. The effect of solar energy system type and soil tillage systems on the amount of water consumption during season (m^3/season).

Solar Energy System Type	Soil Tillage Systems			Solar System Mean
	Rigid-tooth Harrows	**Rotary Harrows**	**Disc Harrows**	
Tracking System	19.69	19.89	19.78	19.79
Fixed System	19.83	20.06	20.01	19.97
LSD (0.05)		N.S		
Mean of Soil Tillage Systems	19.76	19.98	19.90	0.166
LSD (0.05)		0.092		

Bulk density

shows the effect of solar energy Table 4 system type, soil tillage systems and their interaction on bulk density (g/cm^3). The results shows that there is a significant effect of soil tillage systems on bulk density (g/cm^3) as mold board plow with spik-tooth harrows achieved the lowest Average of (1.02) g/cm^3, while mold board plow with rotary harrows achieved the highest Average of (1.22) g/cm^3. This difference is due to the fact that different tillage systems affect the degree of soil friability, where spik-tooth harrows contribute to improving soil structure and reducing soil compaction, while rotary harrows lead to particle rearrangement and increase bulk density due to rotational movements that affect the distribution of particles in surface layers [21].

The results showed that the two-way interaction between solar system type and soil tillage systems had a non-significant effect on the bulk density (g/cm^3). The trackable system with soil tillage systems for spik-tooth combs achieved the lowest average bulk density of (1.02) g/cm^3, while the fixed system and soil tillage systems for rotating combs achieved the highest average bulk density of (1.23) g/cm^3.

Table 4. The effect of solar energy system type and soil tillage systems on bulk density (g/cm$^{3)}$

Solar Energy System Type	Soil Tillage Systems			Solar System Mean
	Rigid-tooth Harrows	Rotary Harrows	Disc Harrows	
Tracking System	1.02	1.22	1.13	1.12
Fixed System	1.03	1.23	1.11	1.12
LSD (0.05)		N.S		
Mean of Soil Tillage Systems	1.02	1.22	1.12	N.S
LSD (0.05)		0.026		

Sorghum crop

Table 5 shows the effect of solar energy system type, soil tillage systems and their interaction on plant yield (kg/ha), the results shows that the type of solar energy system has a non-significant effect as the highest plant yield Average was achieved with the trackable system (2986) kg/ha while the lowest plant yield Average was achieved with the fixed system (2663) kg/ha.

The results shows that the soil tillage systems have a significant effect on the plant yield (kg/ha), mold board plow with spik-tooth harrows achieved the highest plant yield of (2949) kg/ha, while mold board plow with rotary harrows achieved the lowest plant yield of (2597) kg/ha. This is because different tillage systems affect the soil structure, with spik-tooth harrows improving soil aeration and enhancing water and nutrient uptake, while rotary harrows may increase soil compaction and reduce soil permeability, limiting the efficiency of water and nutrient uptake.

The results showed that the two-way interaction between solar system type and soil tillage systems had a non-significant effect on plant yield (kg/ha), as the trackable system and mold board plow with spik-tooth harrows achieved the highest plant yield of 3167 kg/ha, while the fixed system and mold board plow with rotating harrows achieved the lowest plant yield of 2497 kg/ha.

Table 5. The effect of solar energy system type and soil tillage systems on plant yield (kg/ha).

Solar Energy System Type	Soil Tillage Systems			Solar System Mean
	Rigid-tooth Harrows	Rotary Harrows	Disc Harrows	
Tracking System	3167	2697	3093	2986
Fixed System	2730	2497	2762	2663
LSD (0.05)		N.S		N.S

Mean of Soil Tillage Systems	2949	2597	2928
LSD (0.05)		235.0	

Conclusions

The results indicate that the solar trackable system is an innovative and more efficient solution compared with fixed system to power the drip irrigation systems, as the trackable system showed a superior ability to follow the path of the sun's rays throughout the day. The results showed that the trackable system achieved the lowest results for. energy consumption (1.07) kW/h, water consumption (19.79) m^3/season and achieved the highest productivity of sorghum yield (2986) kg/ha. Spik-tooth harrows achieved the lowest bulk density (1.02) g/cm^3 and the highest sorghum yield (2949) kg/ha. Therefore, we recommend The use of trackable solar panels in the operation of drip irrigation systems, as they contributed to improving the efficiency of solar radiation utilization, thus reducing energy consumption, The use of spik-tooth combs with their great efficiency in improving soil structure by reducing bulk density and increasing water permeability, which led to enhanced crop growth and the study recommend the widespread adoption of these integrated solutions to promote sustainable agricultural development and address future challenges related to agricultural and natural resource management.

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