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Effect of Some Engineering Factors on A Traveler Gun Sprinkler performance

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A TRAVELER'S sprinkler is one of the irrigation systems that can increase water efficiency. This system is more efficient than traditional irrigation methods and saves water. The traveling sprayer is designed for operation in open fields. It can be used in various locations that require irrigation, including sports fields, and landscapes. This research aimed to optimize pressure management, nozzle sizes, and sprinkler heights. The experiments were conducted at the Faculty of Agriculture, Aswan University, Aswan, Egypt. Engineering factors were studied, including nozzle size, operating pressure, wetted diameter, and discharge rate. Five nozzle sizes (8, 10, 12, 14, and 16 mm) were tested at three pressure levels (3, 4, and 5 bar). The results showed that the coverage radius increases with high operating pressure and large nozzle size, with a maximum coverage radius (32 meters) recorded when using a 16 mm nozzle and 5 bar operating pressure. It was also noted that the coverage radius was affected by the nozzle's height above the ground. On the other hand, discharge rate increased with increased pressure and nozzle size, with a slight decrease in flow recorded at all nozzle heights. The minimum flow rate was 1.35 l/s when using an 8 mm nozzle at 3 bars, while the maximum flow rate was 5.58 l/s when operating a 16 mm nozzle at 5 bars. This result facilitates determining the operating pressure required to cover the desired irrigation area. The best height was 1.5 m compared to other heights.

Keywords: Sprinkler Irrigation, Traveler gun, Nozzles, Engineering Factors.

Introduction

Irrigation systems currently in use in Egypt face significant challenges due to water scarcity and climate change, necessitating the adoption of innovative irrigation systems to increase water use efficiency. The Egyptian government encourages researchers to innovate and develop modern irrigation systems. Perhaps one of the most important goals of sustainable development for developing countries is to enhance the utilization of renewable energy sources in all sectors in general and the agricultural sector in particular (Elkaoud *et al.*, 2025). Sprinkler irrigation is one of the best irrigation systems, as it is used to irrigate most crops. It is one of the systems that works to rationalize water (Li, Hong *et al.*, 2019; Yongguang *et al.*, 2016). with the traveling gun sprinkler system being one of the most advanced methods for improving water-use efficiency. This system optimizes water distribution by precise application, allowing for controlled water delivery based on crop requirements (Darko, Ransford Opoku *et al.*, 2017). It reduces energy dependency, making it suitable for regions with limited power resources (Wahyudi *et al.*, 2023; Audino, 2019). Water is among the most critical natural resources and a fundamental component of sustainable social development (Zhu, Xingye *et al.*, 2018). However, global freshwater resources are extremely limited, accounting for only 2.5% of

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the planet's total water supply (Aslan, 2024; Lu, Yong-zong *et al.,* 2019; Alzubaidi and Mahdi, 2024). A substantial portion of this freshwater exists as glaciers and groundwater, making direct utilization difficult (Wada *et al.,* 2017; Youssef et al., 2025). Freshwater is under increasing pressure due to rapid population growth, agricultural and industrial expansion, and climate change. Although water covers approximately 71% of the Earth's surface, accessible freshwater constitutes only a minimal fraction, with an uneven geographical distribution (Sachan *et al.,* 2020; Sarwar, Abid *et al.,* 2021). Agriculture contributed 12% to Egypt's GDP in 2019, establishing it as a vital sector in the national economy. It provides employment for 29.6% to 36% of the workforce, a figure expected to rise with continued population growth (Entlaq, 2024). Egypt's annual population growth rate ranges between 1.7% and 2.8%, and this rapid increase has led to a substantial surge in water demand (Mebarki *et al.,* 2020; Youssef *et al.,* 2025). Globally, agriculture is the largest water consumer, accounting for 69% of total water usage, while 23% is allocated to industrial needs and only 8% to domestic consumption (Ramadan *et al.*, 2024; Solaw, 2011). The Nile River serves as Egypt's primary water source, supplying 90–95% of the country's water needs (Rayan *et al.*, 2022). Water scarcity in Egypt is a critical issue, particularly in agricultural irrigation (Hossam, 2017; Zhang, 2017; Awad and Soghir, 2023). Agricultural water consumption in Egypt continues to rise due to increasing food demand and population growth, accounting for 62.152 billion cubic meters (Poble and Mindelis, 2023). Only about 4% of Egypt's land is arable, with the Nile Delta constituting 65% of the country's agricultural land. Most of Egypt's cultivable land is concentrated in the Nile Valley and Delta regions (El-Din, 2013; Stefán, 2023; Abdel-Satar and Goher, 2017). Per capita water availability in Egypt has been steadily declining, dropping to less than 560 cubic meters per year by 2023 well below the global water poverty threshold of 1,000 cubic meters per capita annually. This figure is projected to decrease further due to rapid population growth and climate change impacts on the Nile's flow (Mohanty *et al.*, 2024; Salman, 2024; Indurthi *et al.*, 2024) Modern irrigation systems, such as drip and sprinkler irrigation, play a crucial role in enhancing agricultural productivity and environmental sustainability. In Egypt, these advanced techniques significantly reduce water wastage while improving crop yield and quality (Hedia and Mahmoud, 2024). Studies indicate that sprinkler irrigation can save 20 -30% more water than conventional methods while increasing crop productivity (Kumar *et al.,* 2023; Kahlown *et al.,* 2017; Liu and Darko, 2016). Sprinkler irrigation is a modern technique that distributes water by spraying it into the air, allowing it to fall onto the soil surface like natural rainfall (Kincaid *et al.,* 1996). Sprinkler irrigation is a method that has high application efficiency, which can be further increased when coupled with automation toward precision irrigation (Chauhdary *et al.,* 2024). It distributes water by spraying it into the air, allowing it to fall to the surface of the soil like natural rain (Pan, Qingmin *et al.,* 2024; Lu, Yongzong, *et al.*, 2018). Water is pumped under high pressure through small nozzles, generating fine droplets (Pan, Xuwei *et al,* 2024; Liu, Junping *et al.*, 2021). The water stream breaks up due to variations in exit velocity, mechanical disruption by rotating sprinklers, and the interaction between pump pressure and air resistance. High-pressure pumps ensure uniform and efficient water distribution across large agricultural areas (Chen *et al.,* 2021; Tang *et al.,* 2022). Although traveling gun sprinkler systems perform well in water distribution efficiency, their high energy consumption remains a major challenge (Liu JunPing *et al.,* 2016). Energy use in these systems primarily stems from pump operation and water conveyance (Eziefula *et al.,* 2025; Shani, 2024). The elevated energy demand in high-pressure sprinkler systems (operating at 2–5 bar) increases operational costs (Chen, *Xiaofang et al,* 2024*; Wang et al.,* 2024*;* Chen, Rui *et al,* 2023*)*. Reducing the working pressure of sprinklers can effectively reduce the energy consumption of sprinkler irrigation systems (Chen and Wang, 2021; Hua, Lin *et al.*, 2022). The traveling gun sprinkler system is ideal for dense crops in Egypt, such as sugarcane, potatoes, peanuts, wheat, vegetables, and fodder (El-Alosey *et al.,* 2021; Muhammad Yasin *et al.,* 2000; Khedkar, 2014). Despite requiring substantial initial investment, this system remains an efficient solution for rapidly irrigating large areas (Zhu, and Neibling, 2016; Chen, Rui, *et al.,* 2022). Proper system design, including nozzle selection, pressure adjustment, optimal sprinkler height, and spacing, is essential for maximizing performance. A well-designed system ensures uniform water distribution, enhances water-use efficiency, and reduces operational costs, making traveling gun sprinklers a sustainable choice for large-scale irrigation. This system can save labor, time, electricity, and irrigation water. However, water distribution efficiency in large sprinklers may be low if not properly designed. Limited data are available on the hydraulic characteristics of rain gun sprinklers, prompting this study to investigate the relationship between pressure vs. discharge and pressure vs. throw radius for different nozzle types and sprinkler heights.

Materials and Methods

1- Design goals and criteria.

The traveler gun sprinkler system is an effective solution for water conservation and is environmentally friendly. The system's operating principle integrates modern irrigation technologies with traveler irrigation systems, ensuring uniform water distribution through the gun sprinkler. This enables efficient coverage of large areas with high effectiveness. The traveler gun sprinkler system represents a modern irrigation approach that incorporates energy-saving technology. Its operation is based on sensor-driven technology with variable water application rates, as illustrated in (Fig.1) showing the system's operational workflow.

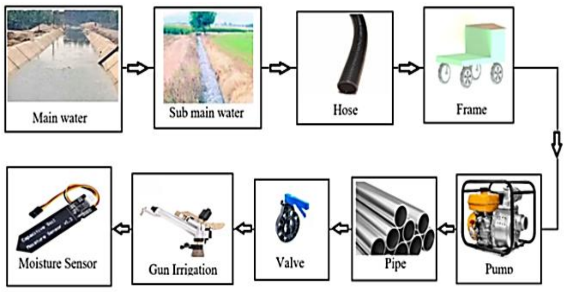

Fig. 1. Traveler gun sprinkler working principle.

The system relies on efficient water distribution through traveler gun sprinkler, ensuring uniform coverage of agricultural areas. Water is pumped from the main source through supply pipes, then transferred via a flexible hose to the traveler gun sprinkler, which distributes water in a circular or sectorial pattern depending on the required setting. The four wheels facilitate the movement of the traveler gun sprinkler between different locations, reducing the need for multiple fixed irrigation systems. The amount of water distributed is controlled based on readings from soil moisture sensors, which send signals to the control unit to adjust water flow or shut off the system once optimal irrigation levels are achieved. This system provides efficient water conservation, reduces waste, and is easy to transport and operate in various agricultural fields.

2-The main components.

Traveler sprinklers were developed to increase water efficiency in irrigation. Their key advantages include their simplicity of manufacture and ease of use, and their components are made from local materials, making them economical and affordable. The system also features easy control of the advance speed, making it ideal for irrigating fields and sports fields. Another key advantage is their remote operation, providing greater flexibility and ease in managing irrigation needs. Field experiments were conducted at Aswan University Stadium, Aswan, Egypt, located at latitude 24.08889°N and longitude 32.89972°E, approximately 85 meters above sea level. Fig.2 illustrates the basic components of a mobile sprinkler system. The system consists of four main components, summarized as follows:

2.1-Frame.

The traveler gun sprinkler frame uses four wheels [400 × 8] to make contact with the earth surface. They are mounted in the frame, and a four-wheeled dc motor pulls the traveler gun sprinkler along. The frame was covered with sheet metal that was 1 mm thick, rectangular tubes (40×40×2 mm) and square tubes (30×30×1mm). The rectangular-shaped frame was made of dimensions of 55 cm height 120 cm length and 90 cm width.

2.2-Power unit.

The power unit used in the traveler gun sprinkler is a 4 Motors DC. They are installed in the frame .The dc motor power for 350 W. Traveler gun sprinkler system moving at different speeds.

2.3-Power supply system.

Two lithium batteries (36 V, 4400 mA) were used as an alternative power source for the DC motor and a battery (12 V) for the electronic circuits.

2.4-Sprinkler irrigation system.

Galvanized iron pipes, sprinkler gun (D = 1.5 in) using nozzle (8, 10, 12, 14 and 16 mm), water pipes (1.5 in) using different heights 1.25m, 1.5m and 2m., hoses (1.5 in) and a gasoline engine pump make up the majority of the sprinkler irrigation system frame.

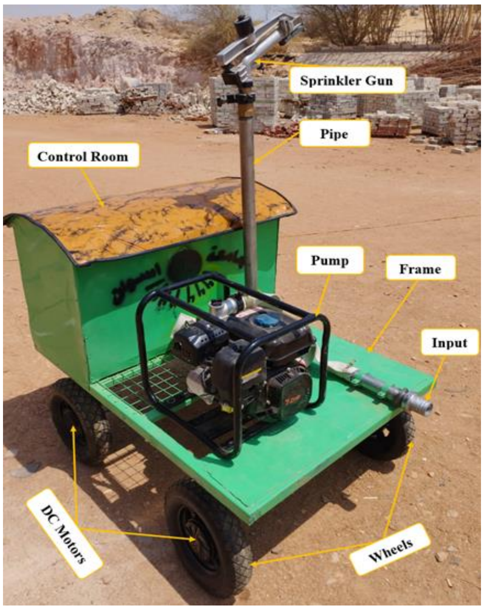

Fig. 2. A photorealistic of the traveler gun sprinkler.

3-Experimental variables.

A series of preliminary experiments were conducted to determine the some important variables that may directly affect the performance of the traveler gun sprinkler. Variables of experiments are as follows:

3.1-Gun nozzles.

In the irrigation process, if the traveler gun sprinkler recounts more than one type of plant, its nozzles a change in the traveler gun sprinkler to obtain different flow rates and different radius suitable for the plant. Accordingly, experiments were conducted using five (8, 10 , 12 ,14 ,16 mm) nozzles.

3.2-Pressure.

Experiments were conducted a traveler gun sprinkler using three Pressures of 3, 4 and 5 bar.

3.3-Height gun sprinkler.

The gun sprinkler was tested under 3 different heights of sprinkler 1.25, 1.5 and 2m. As seen in (Fig.3), the riser pipes were threaded at the frame.

Fig. 3. Different heights of the traveler gun sprinkler.

Results and Discussion

The Initial assessment of a traveler gun sprinkler in Aswan University – Aswan – Egypt, located at 24.08889 N latitude and 32.89972 E, longitude and at an altitude of about 85 m above mean sea level.

1-Pressure - Radius of Throw Relationship.

A detailed study was conducted to analyze the relationship between hydraulic pressure and sprinkler wetting radius, as this relationship is one of the key factors determining the performance efficiency of traveler gun sprinkler in irrigation systems. The study focused on the effect of pressure on the wetting radius using different nozzle sizes (8, 10, 12, 14, and 16 mm), varying the pressure from 3 to 5 bar in 1 bar increments, and evaluating performance at sprinkler heights of 1.25, 1.5, and 2 meters. The effect of pressure on the throw radius of traveler gun sprinkler for various nozzles is shown below.

1.1-Effect of pressure on radius of throw at riser height of 1.25 m.

By analysing (Fig.4), it is observed that increasing the operating pressure results in an increase in the wetting radius, as the higher pressure provides greater thrust to the water jet, promoting a larger wetting radius. This result is consistent with previous studies (Khedkar *et al.*, 2014).

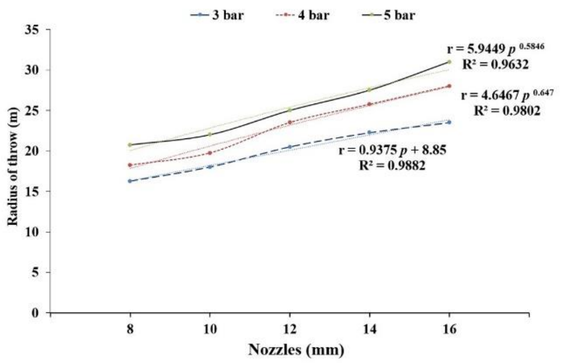

Fig. 4. Radius (m) of wetted strip of Throw at riser height of 1.25m.

Which indicated the effect of positive pressure on traveller gun sprinkler. Regarding the effect of the gun's height, the results showed that the highest radius value was nozzle 16 mm. Increasing the pressure led to a near-linear increase in the wetting radius, as it was observed that the wetting radius increased from approximately 23.5 m at 3 bar pressure to approximately 31 m at 5 bar pressure, with a difference of 8.5 m at a hoist height of 1.25 m.

However, at a hoist height of 1.5 m, the increase was less pronounced, as the wetting radius increased from approximately 25.25 m to 32 m for the same pressure range. This is attributed to the effects of gravity and air resistance, which reduce the firing range at higher altitudes. In general, there is a direct relationship between pressure and wetting diameter. However, this relationship is affected by sprinkler height, with the effect of pressure being more pronounced at lower elevations. These results help improve the design and development of mobile artillery sprinklers to achieve optimal coverage of irrigated areas. They provide valuable guidance for improving the design and development of traveller gun sprinkler efficiency, taking into account pressure and height adjustments for optimal performance. Several mathematical models were developed. The optimal model was selected for each case based on the highest value of the regression coefficient (R^2). The following equations were derived using curve fitting. The selected mathematical models provide accurate analytical tools for evaluating traveler gun sprinkler performance under different operating conditions, contributing to improving the efficiency of irrigation systems and designing them more effectively:

$$r_{(H1)_{5bar}} = 5.9449 \times p^{0.5846} \ldots\ldots\ldots\ldots (1)$$

$$r_{(H1)_{4bar}} = 4.6467 \times p^{0.647} \ldots\ldots\ldots\ldots (2)$$

$$r_{(H1)_{3bar}} = 0.9375 \times p + 8.85 \ldots\ldots\ldots (3)$$

1.2- Effect of Pressure on Radius of Throw at riser height of 1. 5m.

Figure 5 shows the effect of Pressure on Radius of Throw at riser height of 1. 5m.

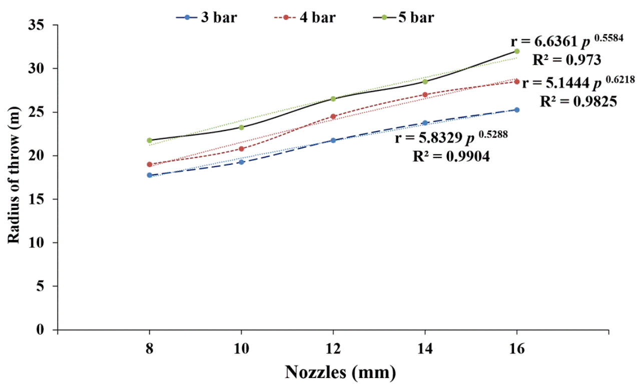

Fig. 5. Radius (m) of wetted strip of Throw at riser height of 1. 5m.

Results showed that the 1.5-meter height at 5 bar operating pressure gave the maximum wet radius 32 meters, but the nozzle 8 gave the minimum wet radius in all operating pressure from 17.75 to 21.75 meters with an increase in pressure from 3 to 5 bar with 1 bar difference. The following equations were derived using curve fitting:

$$r_{(H2)_{5bar}} = 6.6361 \times p^{0.5584} \ldots\ldots\ldots\ldots (4)$$

$$r_{(H2)_{4bar}} = 5.1444 \times p^{0.6218} \ldots\ldots\ldots\ldots (5)$$

$$r_{(H2)_{3bar}} = 5.8329 \times p^{0.5288} \ldots\ldots\ldots\ldots (6)$$

1.3- Effect of Pressure on Radius of Throw at riser height of 2 m.

Figure 6 shows the effect of Pressure on Radius of Throw at riser height of 2m.

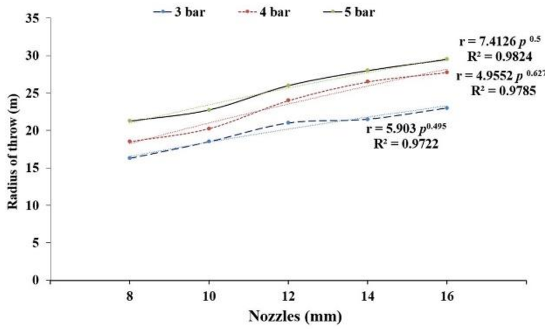

Fig. 6. Radius (m) of wetted strip of Throw at riser height of 2m.

Results showed that the 2 meter height at 5 bar operating pressure gave the maximum wet radius 29.5 meters, but the nozzle 8 gave the minimum wet radius in all operating pressure from 16.75 to 21.25 meters with an increase in pressure from 3 to 5 bar with 1 bar difference. The following equations were derived using curve fitting:

$$r_{(H3)_{5bar}} = 7.4126 \times p^{0.5} \ldots\ldots\ldots\ldots\ldots (7)$$

$$r_{(H3)_{4bar}} = 4.9552 \times p^{0.6273} \ldots\ldots\ldots\ldots (8)$$

$$r_{(H3)_{3bar}} = 5.903 \times p^{0.495} \ldots\ldots\ldots\ldots\ldots (9)$$

2-Discharge - sprinkler height.

To study the effect of pressure on the discharge rate of a (8, 10, 12, 14, and 16 mm) diameter nozzle, the discharge rate was measured at different pressures of 3, 4, and 5 bar in 1 bar increments. In addition, different heights were considered, with sprinkler heights of 1.25, 1.5, and 2 m being used. The effects of the operational parameters, namely operating pressure, nozzles, and nozzle height on the discharge, are shown in Table 1. The variations in the behavior of the system under these different pressures were analyzed, and the results are presented in Figures 7,8 and 9. These show the relationship between pressure and discharge, helping to understand how changes in pressure and height affect nozzle performance.

Table 1. Effect of operating pressure, nozzle size and height of nozzle on discharge.

N	Pressure (P), bar	Nozzle (N×5)	Discharge (l/s)		
			Height of the Nozzle		
			H_1	H_2	H_3
1	3	8	1.69	1.61	1.35
		10	2.02	1.92	1.56
		12	2.55	2.4	2.1
		14	3.7	3.53	3.3
		16	4.89	4.78	4.32
2	4	8	2.12	1.95	1.69
		10	2.38	2.15	1.98
		12	3.4	3.22	2.95
		14	4.29	4.11	3.92
		16	5.52	5.31	5
3	5	8	2.21	2.1	1.91
		10	2.52	2.43	2.25
		12	3.56	3.43	3.13
		14	4.75	4.55	4.2
		16	6.1	5.92	5.58

2.1-Discharge - sprinkler height at Pressure of 3bar.

According to the results in (Fig.7), the show that the discharge of the sprinkler gun increases expressly as the nozzles increase in diameter, as the larger area of the nozzles segment leads to the passage of a larger amount of water. Increased pressure also leads to higher disposition, due to the parcel relationship between pressure and flow rate according to the principles of fluid dynamics. Elevation indirectly affects behavior through changing hydraulic conditions and loss of latent energy. Through analysis, it is clear that the highest behavior is achieved when using large-diameter nozzles (16 mm) with high pressure (5 bar), indicating the importance of accurately selecting these factors to improve the efficiency of traveler gun sprinkler systems. These results contribute to the study of engineering factors that increase the efficient performance of traveler gun sprinkler, helping to optimize water distribution according to plants' needs. It was noted that the discharge of different nozzles at 3 bar operating pressure ranged from 1.35 to 4.89 l/s at different nozzle heights. The maximum discharge of 4.89 l/s for the size of the nozzle was recorded 16mm with a height of 1.25m from the nozzle while there is a slight difference of 1.5m height to discharge of the nozzle 16mm. The minimum discharge of 1.35 l/s was recorded for the size of the nozzle 8 mm with a height of 2 meters of the nozzle.

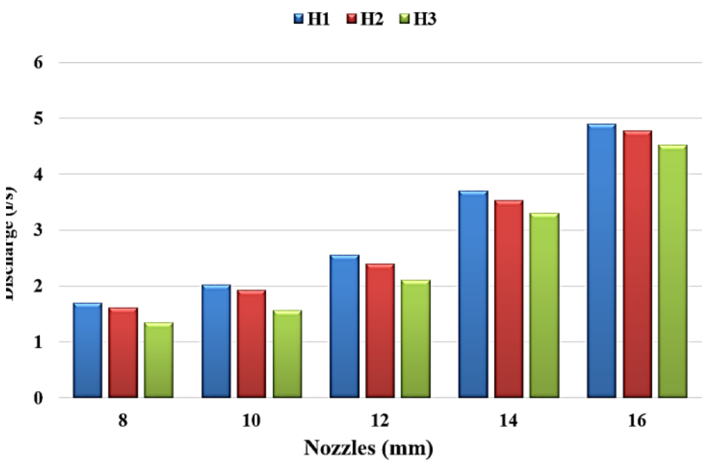

Fig. 7. Effect of sprinkler height (H), nozzle size on discharge at 3 bar operating pressure.

2.2-Discharge - sprinkler height at Pressure of 4 bar.

According to the results in (Fig.8), showed that the discharge of different nozzles at the operating pressure of 4 bar ranged from 1.69 to 5.52 l/s at different nozzle heights. The maximum 5.52 l/s discharge of the nozzle size was recorded 16mm with a height of 1.25m from the nozzle while there is a slight difference of 1.5m to discharge the nozzle 16mm to be 5.31 l/s with 0.21 l/s difference due to the height of the sprinkler gun 25cm increased at a constant pressure of 4 bar. The minimum discharge of 1.69 l/s for the nozzle size was recorded 8 mm with a height of 2 meters from the nozzle.

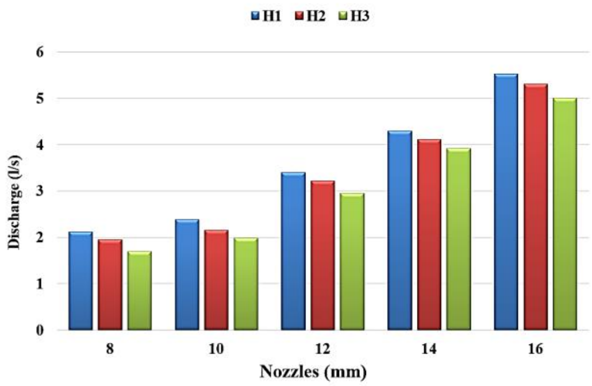

Fig. 8. Effect of sprinkler height (H), nozzle size on discharge at 4 bar operating pressure.

2.3-Discharge - sprinkler height at Pressure of 5bar.

According to the results in (Fig.9), showed that the discharge of different nozzles at 5bar operating pressure ranged from 1.91 to 6.1 l/s at different nozzle heights. Maximum 6.1 l/s discharge of nozzle size was recorded 16mm with a height of 1.25 m from nozzle B. The minimum discharge of 1.91 l/s for the nozzle size was recorded 8 mm with a height of 2 meters from the nozzle. The operating pressure of 5 bar is found to be used in the event that greater quantities of water are required for irrigation of plants, which prefers to use the operating pressure of 4 bar because it is suitable in most working cases and reduces vibrations from the traveler gun sprinkler.

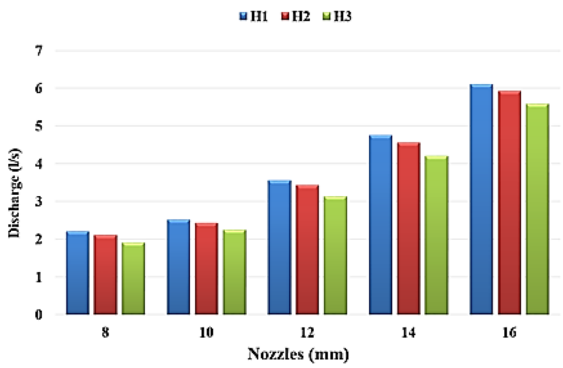

Fig. 9. Effect of sprinkler height (H), nozzle size on discharge at 5 bar operating pressure.

Conclusion

Sprinkler irrigation systems are a modern technology that contributes to the rationalization of water consumption significantly, as a traveler gun sprinkler has been developed to enhance water efficiency. The impact of various engineering factors on traveler gun sprinkler performance was studied, including three levels of operating pressure (3, 4 and 5 bar), five nozzle sizes (8, 10, 12, 14, and 16 mm) and three installation heights (1.25, 1.5 and 2 m) from the Earth's surface. The results showed that the coverage radius increases with high operating pressure and large nozzle size, with maximum coverage radius (32 meters) recorded when using a 16 mm nozzle and 5 bar operating pressure. It was also noted that the coverage radius was affected by the nozzle's height from the ground. On the other hand, water flow rate (disposition) increased with increased pressure and nozzle size, with a slight decrease in flow recorded at all nozzle heights. The minimum disposal limit (1.35 l/s) when using a nozzle was 8 mm in diameter and 3 bar pressure, while the maximum (5.58 l/s) was recorded when operating a nozzle of 16 mm at a pressure of 5 bar. These results provide valuable insights into improving the efficiency of sprinkler irrigation systems, contributing to the sustainability of water resources. This study allows you to know the crunch operating pressure to work with it to get the best disposition and wet diameter in line with the crop and soil type. This contributes to increased irrigation efficiency.

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