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EFFECT OF DIFFERENT PATTERNS AND TYPES OF HEADS ON THE PERFORMANCE OF A PORTABLE SPRINKLER IRRIGATION SYSTEM

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A portable sprinkler irrigation system was installed with the objective of evaluating the performance of the sprinkler system in three patterns (configurations) namely: square, rectangular and triangular. Two sets of sprinkler heads were used; plastic and brass. The study was conducted during the period (March to September 2012) in the Demonstration Farm of the Faculty of Agriculture, University of Khartoum, Shambat, longitude 32o32'E: latitude 15o40'N and altitude 380 m above mean sea level. After installation the system the coefficient of uniformity (CU %) and the distribution uniformity (DU %) were determined for each pattern and each set of sprinkler heads under an operating pressure of 2.5 bars. The completely randomized block design (CRBD) with three replicates was used for each pattern. Due to the change in the application rate and the area, different sprinkler shapes and types of heads resulted in different uniformities. According to the standards specified by Keller (1990), the performance of portable sprinkler system was fell within the acceptable range. Different sprinkler patterns and sprinkler heads significantly ($P \leq 0.05$) affected the system performance. Triangular pattern with plastic sprinkler head gave the highest values of system performance (Cu% = 86, Du% 79) as compared to square pattern with brass sprinkler head (Cu% = 82, Du% 75).It can be concluded that, different sprinkler patterns and head types should be considered as important factors for designing and installing an appropriate portable sprinkler system.

KEYWORDS: Hydraulic performance; Sprinkler patterns; Sprinkler heads

1.INTRODUCTION

The global climate change and its effect on scarce water resources reduced the amount of water available for agriculture (Adam, 2014). Under this circumstance, the use of pressurized irrigation systems can be enhanced the efficiency of water consumption. The irrigation method practiced in Sudan is the surface irrigation, which requires much more water to be applied than that actually needed by crops to compensate for water loss through evaporation, seepage, runoff and deep percolation. The overall efficiency of surface irrigation is between 45 to 60 %. Whereas sprinkler irrigation operates at an overall efficiency approaching 75% (Bush and Mohamed, 2016). Sprinkler irrigation is getting popular in different parts of the Sudan since the mid – 1990s. It is mainly adopted in urban and sub-urban farming in Khartoum State for fodder and vegetables production. The method is mainly used for its high efficiency and flexibility in applying small depths of water. Another motive for the spread of sprinkler irrigation is water conservation, particularly for farmers using ground water for irrigation. Sprinkler manufacturer's catalogues usually identify a recommended range of operating pressure that results in acceptable performance for each sprinkler. The design operating pressure should be as low as possible and within the recommended range. In order to reduce energy consumption and lower operating cost, sprinkler system should operate at the lowest pressure at which acceptable application uniformity and efficiency can be achieved. Application rate is the main design parameter so the rate of water application by a single sprinkler normally varies with distance of throw. It is heavy close to the sprinkler and reduces towards the edge. Michael (1978) concluded that not only the application of the right amount of water to the field, but also its uniform distribution over the field is important.

The water distribution uniformity is an important measure of performance used in the design and evaluation of sprinkler irrigation systems. This uniformity is affected by pressure-nozzle relations, sprinkler heads and spacing and by wind conditions. Wind speed and direction, humidity, temperature and time of test should be recorded along with nozzle size and operating pressure of sprinkler ((Makki, 1996). To make the distribution pattern more uniform, several sprinklers are operated close together so that their distribution overlaps. An efficient sprinkler system depends on a good, arrangement and spacing of nozzles on the laterals, pattern and spacing between laterals which affect irrigation water uniformity (Parchomochuk and Stevenson, 1980). The total variation is used to determine the non-uniformity of the application. Acceptable values of uniformity coefficient (Cu%) vary with the type of crop being grown (Al-araki, 2002). Distribution uniformity (Du%) values are normally much lower than CU values when uniformities are low. Keller and Bliesner (1990) revealed that, For high cash value crops, especially shallow rooted crops, the uniformities should be high (DU values greater than 80% or CU values greater than 87%). For typical fields crops, DU values should be greater than 70% (CU values greater than 81%). For deep rooted orchard and forage crops, uniformities may be fairly low if chemicals are not injected (DU values above 55% and CU values above 72%). Uniformity coefficient should be high (DU values greater than 80% or CU values greater than 87%) whenever fertilizers or other chemicals are injected into the irrigation systems. If uniformity coefficients are lower than these values, system repair, adjustment or modification may be required. If uniformity coefficients are periodically measured (at least annually), system repairs or adjustments can be scheduled when coefficients fall below the above values (Smajstrla et al., 2005). Therefore, the objectives of this study were to evaluate a portable sprinkler irrigation system under Shambat conditions and to determine and compare the performance of a portable sprinkler system under the square, rectangular and triangular configurations with plastic and brass sprinkler heads.

2. MATERIALS AND METHODS

2.1 Experimental work

A portable sprinkler irrigation system was installed and evaluated. The experiment consisted of testing the performance technically of three patterns, namely: the square, rectangular and triangular patterns. For each pattern conducted during March and September 2012 at the demonstration farm of the faculty of Agriculture, University of Khartoum at Shambat (longitude 32o32'E: latitude 15o40'N and altitude 380 m ASL). After installation of the system the coefficient of uniformity (CU %) and the distribution uniformity (DU %) were determined under operating pressure of 2.5 bars. The mean air temperature, evaporation, relative humidity, wind speed and direction during the study period were recorded.

2.2 Irrigation system components and layout

Under each pattern consisted two types of sprinkler heads were used: a single nozzle plastic head (LEGO 55) and a twin – nozzle brass head (JIS2).The performance of the patterns and heads was compared in terms of water distribution (CU% and DU%). Pattern layout spacing was 9×9 m for the square, equilateral triangle of 9 m and 12×9 m for the rectangular pattern (Figs 2.1, 2.2, and2.3). The parameters studied included sprinkler discharge, distance of throw, system discharge requirements and distribution efficiency. The area to be wetted by the sprinkler head was divided in grids of 1.5×1.5 m. Catch cans were placed in the centre of each grid. The volume of water from each container was measured using a measuring cylinder and converted to depth by dividing the water volume by the container top surface area. The completely randomized block design (CRBD) with three replicates for each type of sprinkler head was adopted for layout of the study in three test runs for each configuration. The single point test was adopted and field data were analyzed using the CATCH3D software developed by Allen (1996) to test water distribution under different spacing. The software determined CU% and DU% using input data of the duration of the test, the direction and speed of wind ,the flow rate and water volume in the catch cans. The software is rapid and reduces the complexity and calculation mistakes of the traditional methods. Data was analyzed for each single test and average values were compared across the test runs for the two sprinkler heads and all configurations.

2.2.1 Sprinkler heads

Two types of rotating nozzles were used. The sprinkler heads used were Lego 55 part/full circle (single nozzle and plastic with an opening of 4 mm) and JIS2, heads (twin nozzle and brass with an opening of 4 mm).

2.4 System performance

2.4.1 Christiansen's coefficient of uniformity (CU %)

The pattern uniformity coefficient (CU %) was determined using the following formula as stated by Christiansen's (1942):

$$CU\% = (1 - (\sum x)/mn) \quad \text{……………………………………………………………. (1)}$$

Where:

CU% = Christiansen's coefficient of uniformity (%).

x = deviation of individual observation from the mean value.

n = number of observations.

m = mean value.

2.4.2 Distribution uniformity (DU%)

Water distribution uniformity for each sprinkler pattern was determined from the collected depths in the catch cans using the following equation:

$$DU\% = X25/X \times 100$$

Where:

X25: average low quarterof depths collected in the cans (mm).

X: average water depth collected in all cans (mm).

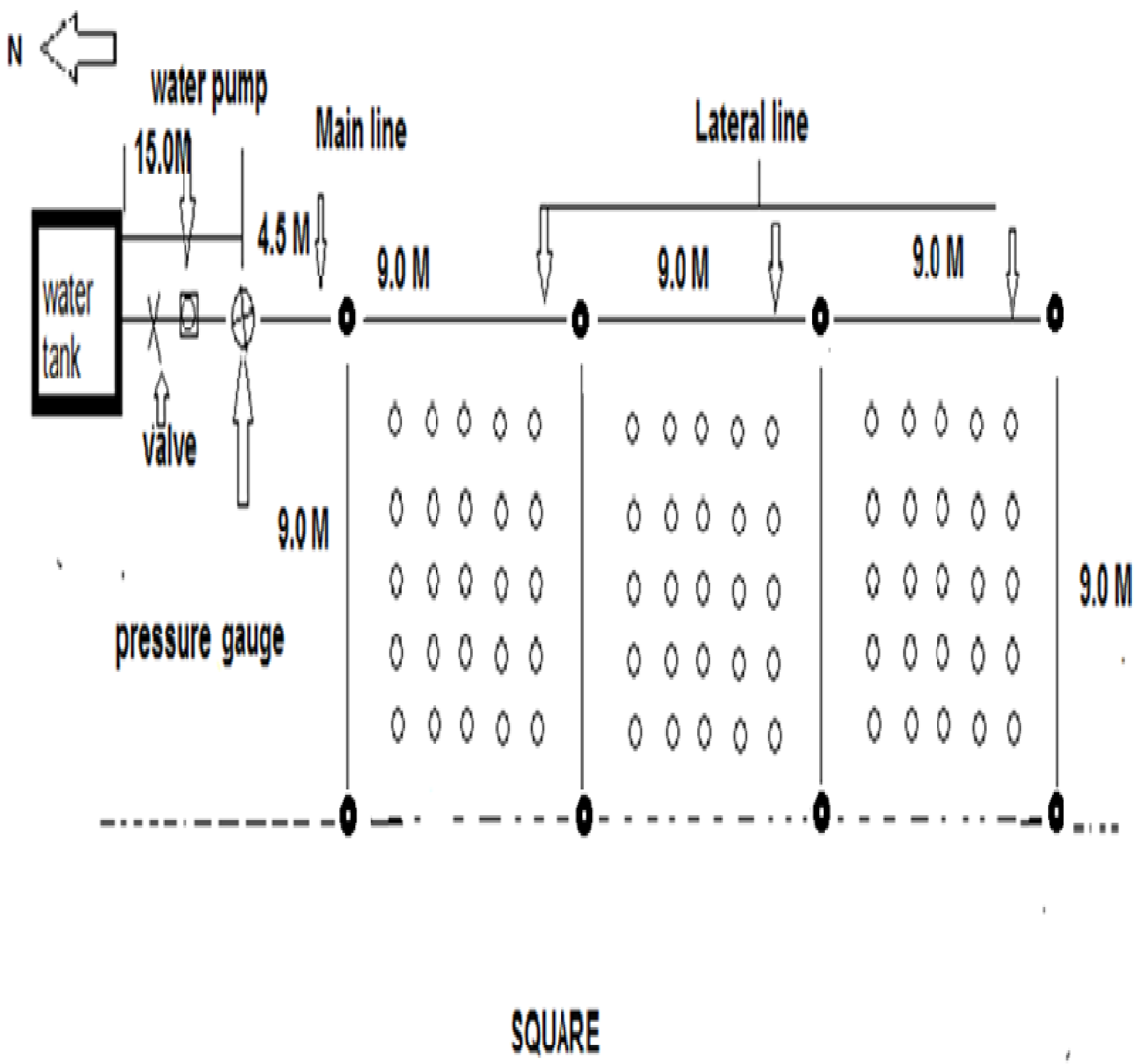

Fig. 2.1. The system components and square pattern (not to scale)

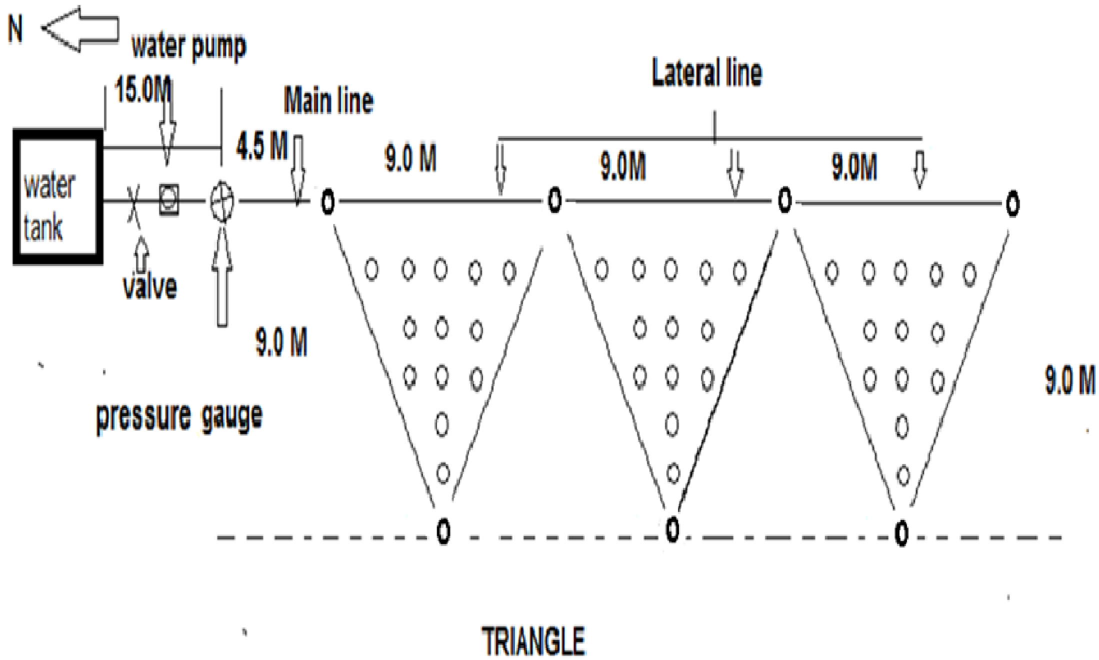

Fig. 2.2. The system components and triangular pattern (not to scale)

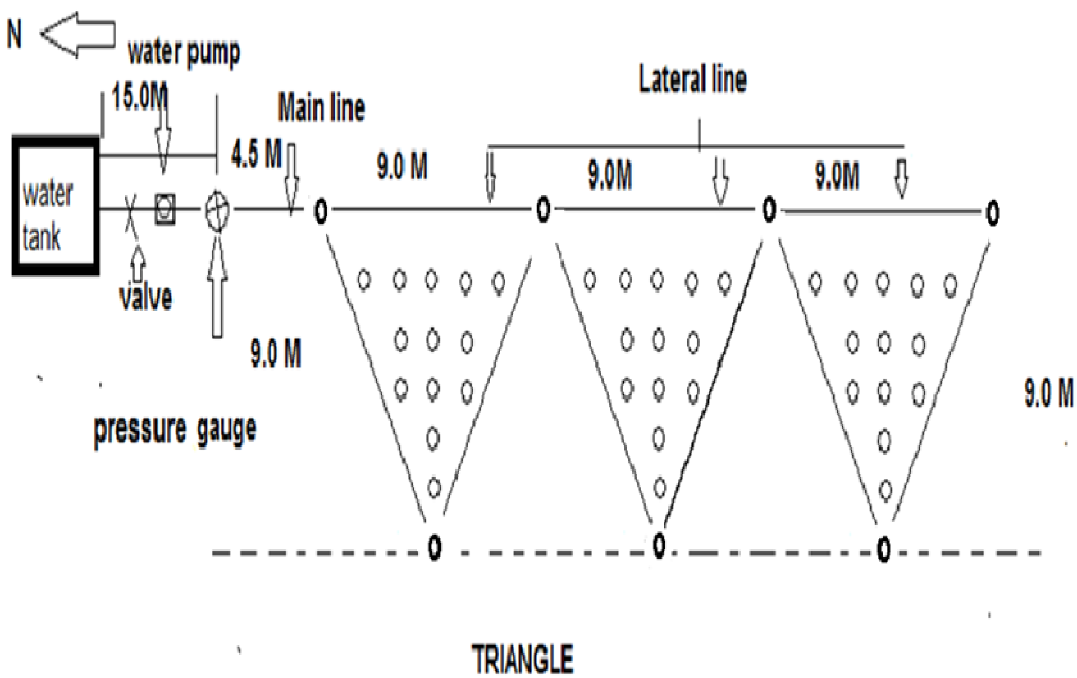

Fig. 2.3. The system components and rectangular pattern (not to scale)

3. RESULTS AND DISCUSSION

3.1.1 Christiansen's coefficient of uniformity (CU%) and Distribution uniformity (DU%)

Christiansen's coefficient of uniformity (CU%) and distribution uniformity (DU%) significantly ($P \leq 0.05$) affected by the different sprinkler heads (Table 1). Plastic sprinkler head recorded the highest values of Christiansen's coefficient of uniformity (CU%) and distribution uniformity (DU%), while the lowest ones were obtained by brass sprinkler heads. These may be due to some factors such as overlapping is occurred during the test run, nozzle size, operating pressure, sprinkler rotation and wind speed and direction. These results were in agreement with the results obtained by Al-Arak

(2002) who reported that, the different operating pressures, nozzle sizes, shapes, heads and angles significantly affected the hydraulic performance of sprinkler system.

3.2 Effect of sprinkler pattern on Christiansen coefficient of uniformity (CU %) and Distribution uniformity (DU%)

As presented in Table 2, Christiansen's coefficient of uniformity (CU%) and distribution uniformity (DU%) significantly ($P \leq 0.05$) affected by the different sprinkler patterns. The highest values were recorded under the triangular pattern followed by the square pattern and the rectangular pattern, respectively. Due to the change in the application rate and the area, different sprinkler shapes resulted in different uniformities. All of these prove satisfactory when adequate overlap is provided. The results were in agreement with the results obtained by Parchomochuk and Stevenson (1980) who found that triangular sprinkler arrangement gave a better uniformity than an equivalent rectangular arrangement.

3.3 Effect of sprinkler pattern and sprinkler heads on the system performance

According to Keller and Bliesner (1990) Christiansen's coefficient of uniformity (CU) and Distribution uniformity (DU %) values were fell within the acceptable range. The interaction between sprinkler patterns and sprinkler heads significantly ($P \leq 0.05$) affected the system performance. Triangular pattern with plastic sprinkler head gave the highest values of system performance as compared to square pattern with brass sprinkler head (Fig. 1). The result was in agreement with the result obtained by Parchomochuk and Stevenson (1980).

Table 1. Effect of sprinkler heads on Christiansen's coefficient of uniformity (CU%) and Distribution uniformity (DU%)

Sprinkler head	Cu%	Du%
Plastic head	88[a]	80 [a]
Brass head	82 [b]	77 [b]
LSD	3.7	2.5

Means followed by the same letter (s) in the same column are not significantly different at $P \leq 0.05$.

Table 2. Effect of sprinkler pattern on hydraulic performance

Sprinkler pattern	Cu%	Du%
Triangle	92[a]	87 [a]
Rectangular	82 [b]	76 [b]
Square	77 [c]	72 [c]
LSD	4.1	3.8

Means followed by the same letter (s) in the same column are not significantly different at $P \leq 0.05$.

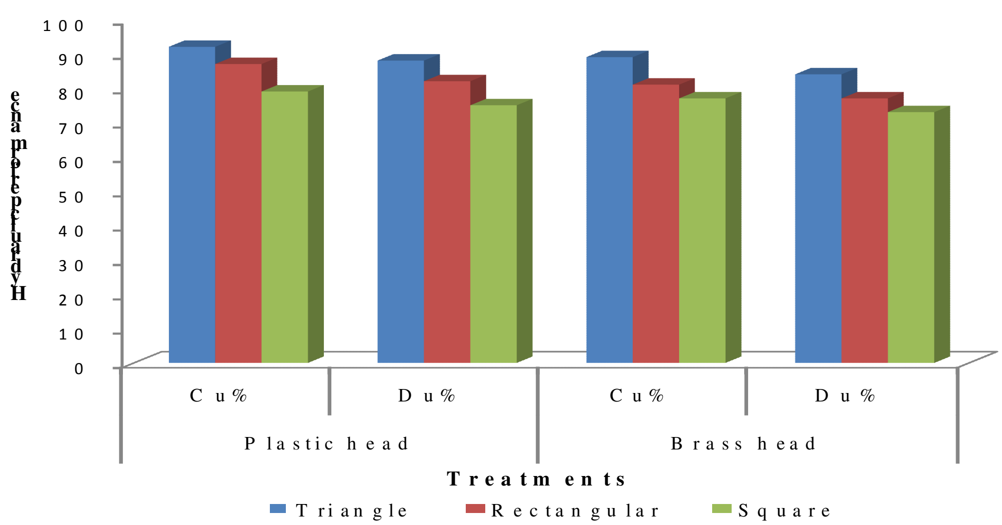

Figure 3.1. Effect of sprinkler pattern and sprinkler heads on the system performance

4. CONCLUSIONS

Due to the change in the application rate and the area, different sprinkler shapes and types of heads resulted in different uniformities. According to the standards specified by Keller (1990), the performance of portable sprinkler system was fell within the acceptable range. Different sprinkler patterns and sprinkler heads significantly ($P \leq 0.05$) affected the system performance. Triangular pattern with plastic sprinkler head gave the highest values of system performance as compared to square pattern with brass sprinkler head.

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