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Effect of Configurations on the Coefficient of Uniformity and Water Distribution Using Single-Nozzle Plastic Sprinkler Heads

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Abstract

This study was conducted during February and March 2014 in the Demonstration Farm of the Faculty of Agriculture, University of Khartoum at Shambat (longitude 32°32′E, latitude 15°40′N and altitude 380 m amsl), on a total area of 40 m × 30 m. The objective of the study was to determine the effect of layout configuration under different operating pressures (1.0, 1.5 and 2.0 bar) on the coefficient of uniformity (CU%) and distribution uniformity (DU%). The tested configurations were the square, rectangular and triangular sprinkler patterns by using single-nozzle plastic sprinkler heads (LEGO). For each configuration, a solid-set sprinkler system was designed and installed. Catch cans were placed at centre of grids of 4 x 4 m. The completely randomized design was used, and treatments were replicated three times. For each treatment the system was run for one hour. The data was analyzed using Minitab Software version 16. The triangular configuration recorded the highest uniformity coefficient and uniformity of distribution under 2 bars operating pressure. The mean values of CU% and DU% of 87% and 80% at $P \geq 0.05$ achieved the following descending order: triangular > square > rectangular configuration. All values obtained were within the acceptable range of standards which described by Keller and Bliesner [11]. The appropriate operating pressure and sprinkler configuration should be considered when designing and installing a solid-set sprinkler system.

Keywords

Distribution Uniformity, Coefficient Uniformity, Pressures, Sprinkler, Configuration, Minitab Software

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1. Introduction

The efficient irrigation system design requires the selection and matching of the sprinkler equipment and spacing to the crop, soil and field shape. An appropriate sprinkler spacing is determined by the type of nozzle used and the operating pressure selected. Every sprinkler-nozzle combination has a specific operating pressure range. Too much pressure will disperse the water stream into a very fine spray resulting in increased evaporation losses or poor distribution of water [1, 2]. At the lower pressure range for any nozzle, the water is broken up into larger drops. When pressure falls too low, the water from the nozzle falls in a circle a small distance away from the sprinkler, thus giving a poor distribution [3, 4].

The square pattern has equal distances running between the four sprinkler positions and it is suitable for irrigating square-shaped areas. The limitation of this pattern is the diagonal distance between sprinklers in the corners and this is usually susceptible to wind effects. To minimise wind effects, closer spacing is recommended depending on the severity of the wind. The rectangular sprinkler spacing has sprinkler positions forming a rectangle with the shorter side of the

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rectangle across the wind and the longer side with the wind, so as to obtain a good coverage [5]. This pattern has the advantage of fighting windy situations and it is suitable for areas with defined straight boundaries and corners. In the triangular pattern, sprinklers are arranged in equilateral triangle formats so that the distance from each other is equal. This pattern allows for lengthy spacing and therefore requires fewer sprinklers compared to the square spacing [6].

2. Materials and Methods

2.1. The Experimental Site

The study was conducted during February and March 2014 to assess the uniformities of a solid set sprinkler irrigation system. The experimental work was carried out in the Demonstration Farm of the Faculty of Agriculture, University of Khartoum at Shambat (longitude 32°32′E, latitude 15°40′N and altitude 380 m amsl) on a total area of 40 m × 30 m to determine the effect of configuration under different operating pressures (1.0, 1.5 and 2.0 bar) on the hydraulic performance of solid-set sprinkler system. The configurations used were rectangular, square and triangular. After installation of the system the coefficient of uniformity (CU%) and the distribution uniformity (DU%) were determined under different operating pressures of 2.0 bar, which was measured by a pressure gauge placed at the beginning of the lateral. The air temperature, relative humidity and wind speed during the study period were presented in (Table 1).

2.2. The Experimental Layout

The study consisted of testing the performance of single nozzle plastic sprinkler heads (LEGO). The performance of these heads was compared in terms of coefficient of uniformity (CU%) and water distribution uniformity (DU%). Plastic cups were used as catch cans and were placed at the centre of grids of 4 × 4 m to collect water from sprinkler heads under catch of the three design patterns. The square pattern layout spacing was 8 × 8 m, 9 × 8 m for the rectangular pattern and 9 × 9 m for the triangular pattern.

Forty-four containers were used for each pattern. 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 catching area.

A completely randomized design with three replications for each type of sprinkler heads was used. The data was analyzed using (Minitab Software version 16) and average values were compared across the test runs for each sprinkler head under the different operating pressures and the three configurations.

The materials used were Pressure gauge; Meter tape; Catch cans; Measuring cylinder and Stopwatch.

2.3. Sprinkler System Performance

Before starting the experiment, the sprinkler system was tested to verify its proper operation within the acceptable performance parameters following the procedure adopted by Makki [7]. These parameters were sprinkler discharge and pressure at the sprinkler head, water application rate (cm/h) and system discharge (m^3/h). The pressure and discharge at the sprinkler head, distance of throw and water application rates were within the range specified by the manufacturer.

2.4. Description of Sprinkler System

The sprinkler system consisted of the following components:

2.4.1. Pump Station

A centrifugal 1 hp electrical pump (ASIA) withdrawing water from the main domestic supply line with maximum head of 32 m and discharge of 108 l/min was used to supply a water tank. Also, a centrifugal electrical pump (Italian) model (LINZ, JRM 4BH) of 1 hp with maximum head of 5.6 m and discharge of 50 l/min was used to lift water from the water tank to the system.

2.4.2. Water Tank

Water was stored in a plastic tank with capacity of 7.5 m^3, the tank was raised on an iron platform 1.5 m high with square base of 2 × 2 m, under three different pressures 1, 1.5 and 2 bar.

2.4.3. Main Line

A PVC plastic pipe with diameter of 25 mm was used as a main pipe line. One end of the line was connected to the pump outlet and the other end was connected to a main valve.

2.4.4. Sub-main

A PVC plastic pipe with diameter of 25 mm was used as a sub mainline. One end of the line was connected to the valve and the other end was connected to the lateral lines.

2.4.5. Lateral Lines

APVC pipe with diameter of 25 mm was used for the lateral lines (3 lateral lines). The length of each lateral line was 19 m.

2.4.6. Sprinkler Riser

Galvanized steel pipes with diameter of 18 mm and 1 m height were connected to the laterals to serve as risers.

2.4.7. Sprinkler Heads

The sprinkler head used was LEGO single-nozzle 1/2" Plastic Impact Sprinklers, Pressure 1 to 3.1 Bar, Flow: 10.2 to 17.7 lpm, Radius: 8.8 to 13.1 m, Adjustable Arc.

The meteorological data was obtained from Shambat metrological station as shown below in (Table 1).

Table 1. Metrological data from Shambat, metrological station.

Date	RH%	Temp. (°C)	Wind speed (m/s)
25 February	20	31	2.5
26 February	8	28	2.5
27 February	17	29	3
28 February	17	30	3.6
1 March	28	30	6.1
2 March	14	29	5
3 March	18	31	3
4 March	20	33	3
5 March	27	33	2.1
6 March	20	35	2.5

3. Results and Discussion

3.1. Christiansen's Coefficient of Uniformity (CU%)

Significant differences ($P \geq 0.05$) were found between the values of CU% under the different configurations (square, rectangular, and triangular) under the three operating pressures (1.0, 1.5 and 2.0 bar). From Table 2, The best values of CU% were recorded under operating pressure 2.0 bar for the different patterns. The highest value of CU% was obtained by the triangular pattern (87%) under 2.0 bar operating pressure. The values obtained under 2.0 bar operating pressure were higher than those obtained under 1.0 bar operating pressure (Figure 1). This result may be due to the fact that under low pressure the water is broken up into large drop falling near the sprinkler [6, 8].

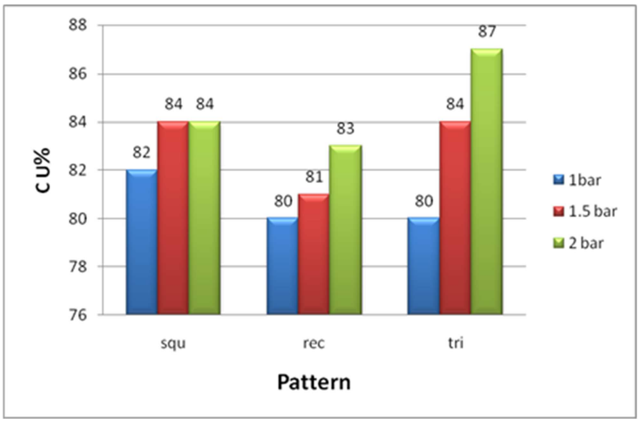

Figure 1. The effect of operating pressures on CU% for the LEGO sprinkler heads under the three patterns.

Table 2. Coefficient of uniformity (CU%) for the three different patterns and pressures for the LEGO sprinkler heads.

Pressure (bars)	Coefficient of uniformity (CU%)		
	Square	Rectangular	Triangular
1.0	82^b	80^b	80^c
1.5	84^a	81^b	84^b
2.0	84^a	83^a	87^a
LSD-Test	1.53	1.71	2.3

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

From Table 2, the values of CU% recorded under the 2.0 bar operating pressure by single-nozzle sprinkler heads and triangular configuration were greater than those recorded by both rectangular and square configurations at same pressures. From Table 2, the values of the patterns were in the following order: triangular > square > rectangular. This result is in agreement with that reported previously [9, 10]. This result may be due to the fact that the triangular pattern overlapping was greater than in the other patterns.

All the values of CU% obtained in this study, for all the single-nozzle sprinklers heads (LEGO) were in the acceptable range [11].

3.2. Distribution Uniformity (DU%)

As shown in Table 3 and Figure 2, significant differences ($P \geq 0.05$) were found between the values of DU% under the different pressures tested (1.0, 1.5, and 2.0 bar) and under the different configurations (square, rectangular and triangular) for the single-nozzle sprinkler heads LEGO used. The highest value for DU% was obtained under the triangular pattern was 80% under 2.0 bar operating pressure. From Table 3, the values obtained under 2.0 bar operating pressure were higher than those obtained under 1.0 bar operating pressure for the three configurations as shown in Figure 2.

Table 3. Distribution uniformity (DU%) for the three different patterns and pressures for the LEGO sprinkler heads.

Pressure (bars)	Distribution uniformity (DU%)		
	Square	Rectangular	Triangular
1.0	72^c	72^b	73^b
1.5	74^b	72^b	74^b
2.0	79^a	77^a	80^a
LSD-Test	1.70	3.40	4.2

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

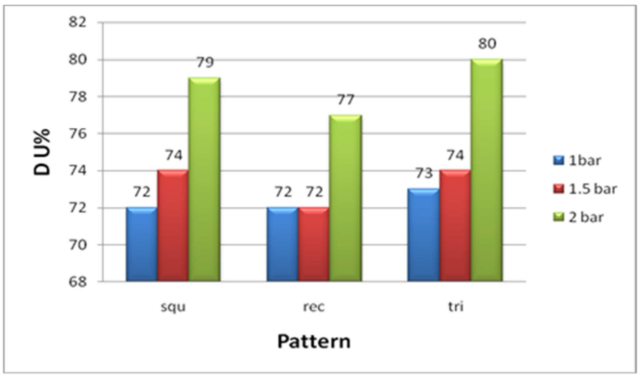

Figure 2. The effect of operating pressure on DU% for LEGO sprinkler heads under the three patterns.

From (Table 3) the values of DU% recorded under the 2.0 bar operating pressure under the LEGO sprinkler heads were in the following order: triangular > square > rectangular. This result is in agreement with that reported in previous [9, 10]. This result may be due to the fact that under the triangular pattern the overlapping was greater than in the other patterns. The value of DU% under the triangular pattern and 2.0 bar operating pressure for the LEGO sprinkler heads was 80% which was higher than the 65% which reported by Makki [7]. This result may be due to the close spacing and low wind speed during this study and suitable operating pressure. All values in all the tests of DU% were greater than the minimum acceptable DU% of the 60% which was specified by Keller and Bliesner [11]

4. Conclusions

The study was investigated three different configurations of sprinkler patterns under different operating pressures (1.0, 1.5 and 2.0 bar) on the coefficient of uniformity (CU%) and distribution uniformity (DU%). The results revealed that, a triangular configuration under all tested operating pressures for the single-nozzle sprinkler heads recorded higher values on DU% and CU%. The mean values of 87% and 80% for CU% and DU% achieved the following descending order for the tested configurations: triangular > square > rectangular. All values of DU% were greater than the minimum acceptable value of 60%. Also, the study recommended that, in order to install a solid-set sprinkler system the convenient operating pressure and configuration must be considered.

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