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Performance of Linear Move Irrigation System under Egyptian Conditions

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Abstract

The efficiency of irrigation as a standard engineering measure has been traditionally used to assess water use management. The objective of this study was to evaluate the technical performance of linear move sprinkler irrigation such as operating speeds for different specifications. Catch cans method was conducted to evaluate the distribution uniformity (DUlq) and the Christiansen coefficient uniformity (CU), evaluation was done at a private farm for two linear move irrigation systems: LM1 (linear move, 6" diameter number of the nozzle orifice 17 attached with 10 L min^{-1} flow) and LM2 (linear move, 8" diameter number of the nozzle orifice 25 attached with 20 L min^{-1} flow) under three different system speeds. The collected water after the irrigation system full passing over the can's lines was measured using the graduated funnel to calculate the DUlq and CU. Ideal operating LM1 at the intermediate system speed (75% of the standard irrigation system speed equivalent to 22.5 m h^{-1}), operating LM2 at the lowest system speed (50% of the standard irrigation system speed equivalent to 15 m h^{-1}) recommended for the uniform irrigation water distribution.The results will improve the selection of travel speed when the water application uniformity of linear move irrigation system is evaluated.

Keywords: Linear move, CU, DU, System speeds.

1. Introduction

Future demand growth will slow further. If at the global level, the production potential exists to cope with increasing demand, developing countries will be more dependent on agricultural imports, and production in poor areas must be increased if food security has to be improved **(Faurès et al. 2002).**People have adapted to low and uneven rainfall throughout history by either living along riverbanks or carefully stewarding and maintaining local water supplies. The invention of large-scale irrigation technologies in the nineteenth century radically altered the balance between man and water **(Briscoe and Qamar, 2006)**. A sprinkler "throws" water through the air to simulate rainfall, whereas the other irrigation methods apply water directly to the soil, either on or below the surface **(Scherer, 2010)**. Low values of CU are usually indicators of a faulty combination of factors such as nozzle sizes, operating pressure and spacing of sprinklers **(Montero et al. 2000)**. Another parameter is distribution uniformity. The DU is defined as the ratio of the mean depth caught on the quarter of the field receiving the least amount, divided by the mean depth caught on the entire field, and multiplied by 100 to express this as a percent **(Ascough and Kiker, 2002)**. Irrigation efficiency as a standard engineering measure has been traditionally used to assess water use management **(Omezzine and Zaibet, 1998)**.

The objectives of this study were to evaluate the water application uniformity, to evaluate the performance of a linear move irrigation system equipped with two types of low-pressure sprinklers,

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and to investigate the effect of travel speed on water application uniformity.

2. Materials and methods

Two linear move irrigation systems were tested at a private farm in Mendisha village, Bahariya Oasis, The Western Desert, El-Giza Province, the latitude of 28° 13′ 36″ N and longitude of 29° 01′30″ E. The mechanical analysis of soil was measured in **Table 1**.

Table 1
The mechanical analysis of soil in the experiment location at Baharya Oasis

Soil depth, cm	Sand, %	Silt, %	Clay, %	Soil texture
0 – 20	77	12	11	Sandy
20 – 40	74	12	14	Sandy
40 – 60	74	12	14	Sandy

Linear move irrigation system specifications

Two linear move irrigation systems experimented; one system had 3 spans 6" diameter with 45 m long, 135 m as total long and another system had 3 spans 8" diameter with 45 m long, 135 m as total long. The first linear move (LM1) had 16 pieces have the number of the nozzle orifice 17 attached with each span after the pressure regulators (20 psi), low drift nozzle (LDN; 3 mm orifice diameter, 10 L min^{-1}), the height between the nozzle and the soil surface was 1.5 m .

The second linear move (LM2) had 3 spans 8" diameter with 16 pieces have the number of the nozzle orifice 25 attached with each span after the pressure regulators (20 psi), low drift nozzle (LDN; 5 mm orifice diameter, 20 L min^{-1}), the height between the nozzle and the soil surface was 1.5 m.

Performance evaluation test and calculations of the studied irrigation systems

The performance evaluation process was done under the effect of three different system speeds (50%, 75% and 100% from the system speed, or 15, 22.5 and 30 m h^{-1}, respectively). Catch cans were used, 600 mm volume and 6.5 cm diameter for each one and were fixed on the soil surface in 3 lines, 3 m between each other and 1 m between the lines.

Figures (1) and (2) show the experimented LM irrigation systems, and the catch cans during the test. System speed was fully automatic controlled using a control panel with a power timer.

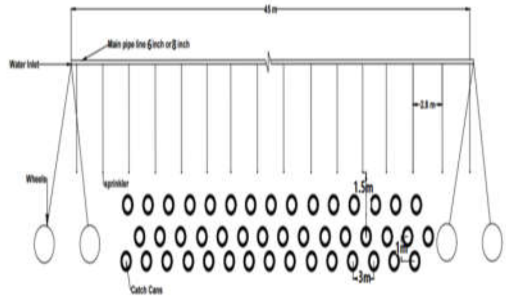

Fig. 1. Linear move irrigation system specifications and catch cans under the system during the performance evaluation process

Fig. 2.Linear move

Two quantitative measurements were calculated. The low quarter distribution uniformity (DU) was determined as the ratio of mean depth caught of one-fourth of the field receiving the least amount to mean depth caught on the entire area according to **Michael (1978)** as shown in **Eq. 1.**

$$DU_{lq} = \frac{\overline{V_{lq}}}{\overline{V_{tot}}} \quad \textbf{(1)}$$

Where

$\overline{V_{lq}}$ is the average of the lowest one-fourth of catch cans measurements (mL).

$\overline{V_{tot}}$ is the average of the application overall catch cans measurements (mL).

The Christiansen Uniformity (CU) was calculated as in **Eq. 2., (ASAE Standards, 2001).**

$$CU = 100 \times \left[1 - \frac{\sum_{i=1}^{n} \left| V_i - \overline{V} \right|}{\sum_{i=1}^{n} V_i} \right] \quad \textbf{(2)}$$

Where

V_i is the individual catch cans measurement (mL).

$\overline{V}$ is the average volume of the application overall catch cans measurements (mL).

1.1. Statistical analysis

Application depth of the water was determined by dividing the size of water gained in the catch cans by those cross-sectional areas, to collect water from sprinklers to study the effect of the experimental treatment on water uniformity (distribution uniformity (DU), and coefficient uniformity (CU). The performance of the sprinkler irrigation system was evaluated three times at early morning, 12 pm and night which expressed as three replicates for the statistical analysis, which was split-plot analysis according to **Snedecor and Cochran (1980),** linear move system type in the main plot and the system speed in the sub main plot.

It is preferable to use confidence intervals tests for the comparisons because these allow for objective decisions. So, the use of graphs and statistical confidence tests (t-test, and regression) are the most used approach for simulation model operational validity (**Mehanna et al., 2015**).

3. Results and Discussion

Performance of linearmove irrigation system

Figures (3 and 4) show the relationship between system speed and DUlq and CU, respectively, for the LM1 and LM2, indicating that increasing system speed from 15 m h^{-1} to 30 m h^{-1} caused a reduction of DUlq and CU values. The intermediate system speed 75% of the standard speed for the LM1 gave the lowest values of DUlq and CU. This impact was high using LM1 comparing with LM2, for that, using LM2 is good for distributing irrigation water uniformly.

This result can be explained by the fact that increasing the forward speed resultedlessening CU and DU which may be attributed to the influence of wind drift in desert.

Tables (2 and 3) show the individual effect of the linear move irrigation system (the average of the three speeds) and system speed on the calculated DUlq and CU, respectively. Linear move irrigation system LM2 gave the high values of DUlq and CU, 85.34% and 80.41%, respectively, that was with significant differences comparing with LM1, where LM1 indicated the lowest average values of DUlq and CU in **Table 2.**

The results are in line with the outcomes of **Bigdeli and Ojaghlou (2021)**, which stated that indicators including Christiansen's uniformity coefficient (CU) and distribution uniformity of low quarter (DUlq) were used to describe the performance of selected irrigation systems. For LM systems, the averages of CU values were calculated as 81.7% and 72.3%, respectively.

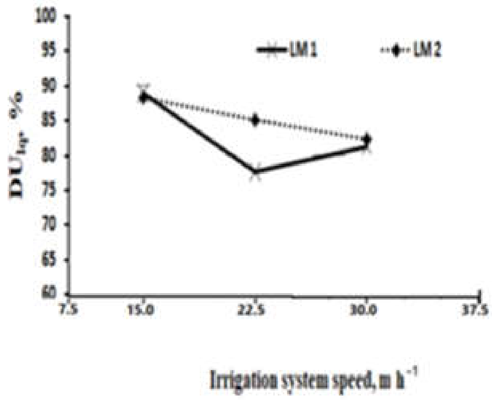

Fig. 3.The relationship between system speed, DU_{lq} for LM1 and LM2

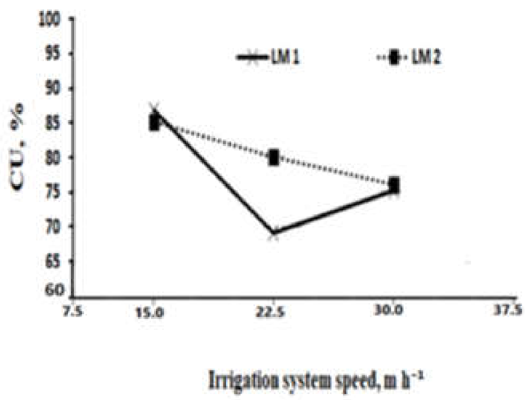

Fig. 4.The relationship between system speed, CU for LM1 and LM2

Table 2
The overall average uniformity and statistical analysis of catch cans data for the studied two linear move systems

Irrigation system	DU_{lq}, %	CU, %
LM 1	82.61 [a]	77.06 [b]
LM 2	85.34 [b]	80.41 [a]
Significance under 5% level	**2.05**	**3.29**

The effect of system speed (average of the two systems) on DUlq and CU is illustrated in **Table 3**. The highest means of DUlq and CU were detected using the lowest system speed (50% of the standard irrigation system speed equivalent to 15 m h^{-1}), followed by the highest system speed (100% of the standard irrigation system speed equivalent to 30 m h^{-1}), on the other hand, the lowest values were obtained using the intermediate system speed (75% of the standard irrigation system speed equivalent to 22.5 m h^{-1}).

Table 3
The average uniformity and statistical analysis of catch cans data for the studied systems speeds

System speed,m h^{-1}	DU_{lq}, %	CU, %
15.0	88.73 [a]	85.95 [a]
22.5	81.35 [b]	74.65 [b]
30.0	81.86 [b]	75.61 [b]
Significance under 5% level	**2.89**	**4.06**

These results were consistent with the finding of **Mohamed et al. (2018)**, which stated said that linear move irrigation system (LMIS) are widely used. Distribution uniformity is considered a good indicator of the system performance.

The interaction between the studied experimental factors (irrigation systems and irrigation system speed) is written in **Table 4**. All differences between means of DUlq were significant. The highest values of DUlq and CU were gained using 15 m h^{-1} system speed for the two studied LM1 and LM2 irrigation systems, 88.9% and 88.55%, respectively without significant difference between them, the same trend was obtained for CU, 86.78% and 85.11%, respectively. Generally, the highest studied speed gave the lowest values of DUlq and CU for LM2. Furthermore, operating LM2 at the lowest system speed (50% of the standard irrigation system speed equivalent to 15 m h^{-1}) are the proper specifications for uniform irrigation water distribution.

These results were consistent with the finding of **Gültaş et al. (2019),** reported that the linear-move irrigation machine could be useful of large areas due to easy-use operating procedure, highly effective water distribution etc. The tests have shown that the annual maintenance of the linear-move irrigation system has a significant effect on the decrease in CU. On the other hand, the high initial investment cost can be considered as a disadvantage. 30, 40, and 50 m h^{-1} operating speed were used. Water uniformity coefficients values were varied between 74.72-86.50%.

Table 4
The average uniformity and statistical analysis of catch cans data for the studied two linear move systems as affected by system speeds

Irrigation system	System speed, m h^{-1}	DU_{lq}, %	CU, %
	15.0	88.90 [a]	86.78 [a]
LM 1	**22.5**	77.64 [d]	69.22 [d]
	30.0	81.31 [c]	75.19 [c]
	15.0	88.55 [a]	85.11 [a]
LM 2	**22.5**	85.07 [b]	80.08 [b]
	30.0	82.41 [c]	76.03 [c]
Significance under 5% level		**2.36**	**3.32**

4. Conclusion

Evaluating the irrigation system is a necessity to ensure appropriate water application and uniformity, selecting the appropriate system to achieve high yield, optimum selection forward operating speed and reducing the total cost and energy requirements. Evaluate the distribution uniformity (DUlq) and **the Christiansen uniformity (CU**), the evaluation was done for two linear move irrigation systems: LM1 and LM2 under three different system speeds (50%, 75%, and 100% of the standard speed of the system or 15 m h^{-1}, 22.5 m h^{-1}, and 30 m h^{-1}, respectively) Experiments results revealed that DUlq (88.90%, 77.64%, and 81.31%) for LM1, and (88.55%, 85.07%, 82.41%) for LM2, also for CU (86.78%, 69.22%, 75.19%) for LM1, and (85.11%, 80.08%, and 76.03%) for LM2. Ideal operating LM1 at the intermediate system speed (75% of the standard irrigation system speed equivalent to 22.5 m h^{-1}), operating LM2 at the lowest system speed (50% of the standard irrigation system speed equivalent to 15 m h^{-1}) are recommended for the uniform irrigation water distribution.

5. Conflicts of interest

There are no conflicts to declare.

6. Formatting of funding sources

This research had not been received any external funding.

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