Sudan J. Des. Res. Vol. 12 (1) :73-83, 2020

Performance Evaluation of a Semi- portable Solid- set Sprinkler Irrigation System at Khartoum State*

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Abstract: A field experiment was carried out during seasons 2007 and 2008 at Elailafoon area30 km south east of Khartoum on the eastern bank of the Blue Nile. The objective of the study was to evaluate the performance of a semi portable solid set sprinkler system when installed in two patterns (spaces), namely, square pattern (18m × 18m) and rectangular pattern (12m × 18m). The design was a randomized complete block design with three replications. Catch cans were carried out to determine the performance of irrigation applied by the semi portable solid set. The distribution uniformity coefficient (DU), Christiansen coefficient of uniformity (CU), application rate (AR) and application efficiency (Ea) of the irrigation system were also determined. Results showed that distribution uniformity coefficient, Christiansen coefficient of uniformity application rate and application efficiency in the rectangular pattern were significantly higher than that found in the square pattern. The values of DU and CU for the square and rectangular patterns were 63%, 69%, 70% and 75%, respectively. The application rate and application efficiency for the square and rectangular patterns were 2 mm/h, 2.5 mm/h, 63% and 78%, respectively. It can be concluded that the sprinkler pattern has a marked effect on the performance of the semi portable solid set sprinkler irrigation system; accordingly the rectangular pattern achieved a better results than the square pattern.

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* Part of an M.Sc. Thesis presented by the first author to the University of Khartoum

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Keywords: Sprinkler irrigation; Distribution uniformity; Application rate; Solid- set; Application efficiency.

INTRODUCTION

The performance and management of irrigation systems should be checked on regular basis. It is important to know the operating characteristics of the irrigation system and also to determine if the actual performance meets the required industry standards. The performance of sprinkler irrigation systems must be improved in order to save water and energy. This generally requires an improvement in the process of management and application of water (Tarjuelo *et al*., 1992).Solid set sprinkler irrigation systems are those in which sprinklers, with their assorted riser, lateral, and manifold pipes, are placed in a regular pattern over the entire irrigated area.

There are broadly two categories of performance indicators. One category evaluates the effectiveness of application or the uniformity of the system and the other evaluates how well the system is managed in terms of the amount of water applied compared to the amount that should have been used (Connellan, 2002).Uniformity of water application can be measured using catch cans set on or near the soil surface. Several uniformity coefficients have been developed as described by Connellan (2002), as: Distribution uniformity coefficient (DU) and Christiansen coefficient of uniformity (CU). Distribution uniformity is a measure of evenness of water application by sprinkler systems. The Christiansen coefficient of uniformity is also widely used in the broad irrigation industry. Acceptable values of uniformity coefficients vary with the type of crop being grown and the specific uniformity equation used (Smajstrla *et al*., 2005).If uniformity coefficients are lower than predetermined values, system repair, adjustment or modification may be required. A sprinkler irrigation water distribution pattern depends on system design parameters (such as sprinkler spacing, operating pressure and nozzle diameter) and on environmental variables namely wind speed and direction (Keller and Bliesner, 1990).

The application rate for a sprinkler is the amount of water applied to a given area measured in millimeter per hour. The most used criterion is to have the application rate equal to or less than the water intake rate of the soil. Application rates under field conditions need to be measured to verify irrigation system designs and to determine whether changes in application rates have occurred with time (Smajstrla *et al*., 2005).

Water application efficiency is an irrigation concept that is very important in both system design and irrigation management. It can be divided into two components water losses and uniformity of application (Ramazan *et al.,* 2005).

In Sudan, surface irrigation is the dominant method used in all major irrigated schemes. This method is characterized by loss of large amount of water. There is now a growing awareness to introduce modern irrigation systems like sprinkler and trickle. These systems are characterized by a high overall efficiency. Sprinkler irrigation systems can attain irrigation efficiencies of greater than 80% if adequately designed and managed (Keller and Bliesner, 1990). There are many factors (Design, management and weather conditions) which affect the performance of sprinkler irrigation system. Thus, such studies are needed to assess the performance of the semi portable solid set sprinkler system under different field conditions in order to identify which factors are responsible for improper performance as well as making required amends. Therefore, the objective of this study was to evaluate the performance of semi portable solid set sprinkler irrigation system when installed in two patterns (square and rectangular) under Elailafoon conditions (South east Khartoum).

MATERIALS AND METHODS

A field experiment was carried out on January during seasons 2007 and 2008 at Elailafoon area30 km south east of Khartoum on the eastern bank of the Blue Nile. It is confined between latitude 15°27'N and longitude 32°46'E, with an altitude of 389 m above mean sea level. The experimental field is relatively flat.The soil of the experimental site is clay soil, and can be classified as subangular blocky structure.
Infiltration rate was measured by using double ring infiltrometer, which was 4.8mm/h.

A semi portable solid set sprinkler irrigation system was installed for forage production. The covered area was 4 feddans. The components of the solid set system are shown in (Fig.1).The system was tested to determine the application rate (AR), the distribution uniformity (DU), the Christiansen coefficient (CU) and the application efficiency. Test was conducted with two laterals consisting of four sprinklers per lateral installed in a square configuration of 18m × 18mand rectangular configuration 18m × 12m.Arotating brass nozzle with an opening of 4 mm and jet angle 30° was used in the system. The sprinkler heads were mounted on risers. The height of risers used for the test was 70 cm. The catch cans method for uniformity testing was used as described by Smajstrla *et al.*(2005) (Fig2).Cans were placed at the mid points between sprinkler heads, the spaces between cans were 2 m and the space between any sprinkler head and the nearest can was 1.5 m. After every test the catch cans were collected and the volume of water was measured and converted to water depth (mm). Before every test, pressure was measured using pressure gauge and then recorded. The system was operated for 30 min. for every test. Each pattern was tested three times. A randomized complete block design with three replications was used. Tests were carried out in the afternoon at 3pm and 4 pm and under moderate conditions. Humidity, temperature and wind speed were recorded.

Distribution uniformity (DU): It was computed by dividing the average low quarter caught in the cans by the average depth caught in all cans, using the following equation (Connellan, 2002):

$$DU\% = \frac{M_{25} X\ 100}{M} \qquad (1)$$

Where:

M = average value of all catch can readings, (mm).

M_{25} = average of lowest 25% of readings, (mm)

Christiansen coefficient of uniformity (CU): It was calculated using the following equation (Connellan, 2002):

$$CU\ \% = \left(1 - \frac{\Sigma Md}{Mn}\right) x\ 100 \qquad (2)$$

Where:

CU %= Christiansen coefficient.

M = average value of all can readings (mm).

ΣMd= total of deviation of each reading from the average (mm).

n = number of can readings.

Application rate (AR): The application rate for the four sprinklers was calculated using the following equation (Smajstrla *et al.*, 2005):

$$AR = \frac{AVG}{sprinklers\ run\ time\ (hour)} \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where:

AVG = average depth of water measured (mm).

Application efficiency (Ea%): It shows the relationship between depth of water collected by catch cans and depth of water discharged by sprinkler. The difference between them is considered a loss. It was calculated using the following equation suggested by Israelsen *et al.* (1967).

$$Ea\ \% = \frac{Ws}{Wf} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where:

Ws = the average depth of water caught in the cans

Wf = the average depth of application.

The data were analyzed using Statistix 8 software computer program for analysis of variance and means separation.

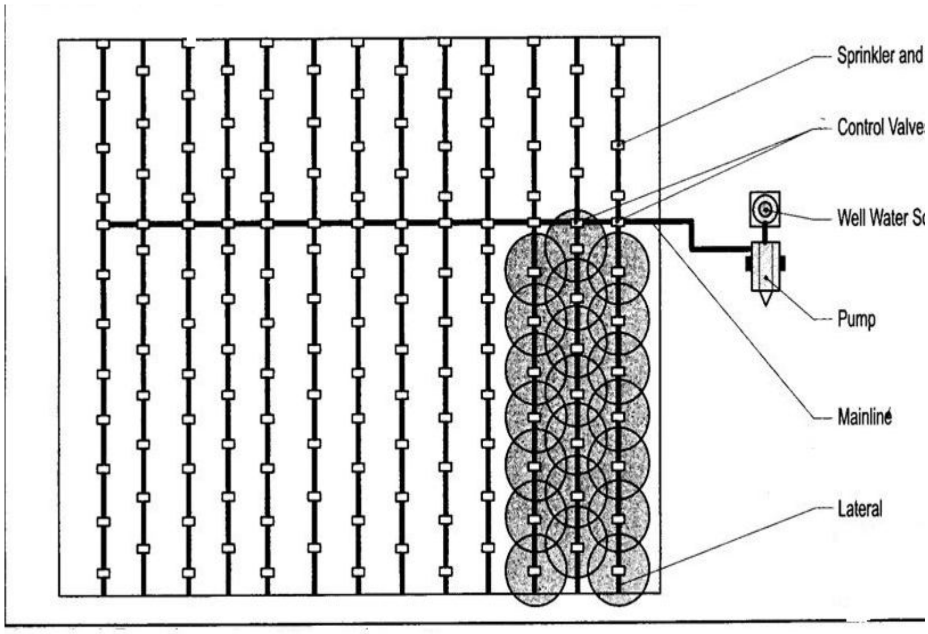

Fig.1. Components of semi-solid set system

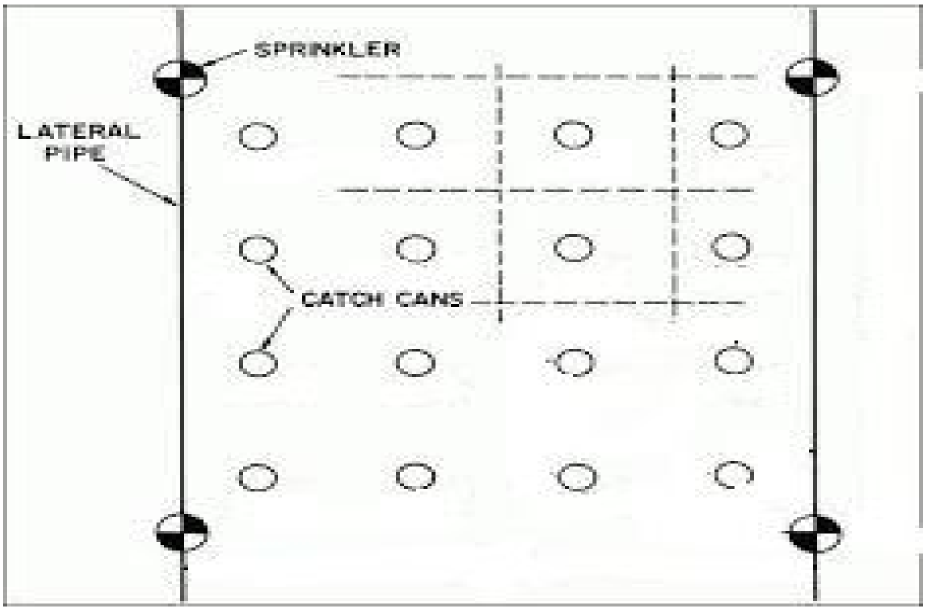

Fig.2 Catch cans arrangement

RESULTS AND DISCUSSION

The results showed there were significant differences in the distribution uniformity(DU) and Christiansen coefficient of uniformity(CU) between the two patterns. The highest values of DU and CU were recorded under the rectangular pattern (18 m × 12 m), it was 70 % and 75 %, respectively. While the square pattern (18 m × 18 m) recorded 63% and 69 %, respectively (Fig. 3).The rectangular pattern performed much better than the square pattern. However, these values of DU and CU for both patterns were considered relatively low when compared with values recommended by Smajstrla *et al*.(2005) and Keller and Bliesner (1990).Sprinkler uniformity is generally affected by the combination of wind speed/direction, operating pressure and sprinkler spacing. In this study low values of DU and CU may be attributed mainly to leak losses which were observed from the coupling joints of main and laterals. These losses decrease the operating pressure particularly at sprinklers, because sprinkler effectiveness is reduced by operation at either high or low pressures. As a result the water is not uniformly distributed. In addition, the low values of uniformity may be due to sprinkler spacing. This may have been due to the fact that in the square pattern the diagonal distance between sprinklers in the corners was usually not full covered. Similar findings were observed by Ramazan*et al.*(2005).

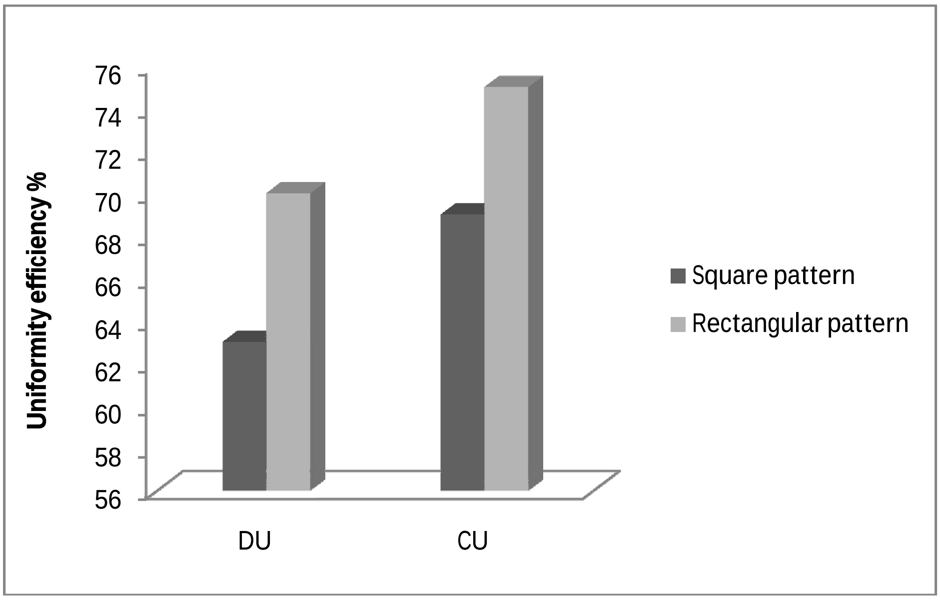

Fig. 3 DU and CU uniformity coefficients of the two patterns

Fig.4 shows that the application rate in the rectangular pattern was significantly higher than that of the square pattern. The highest value of average application rate was 2.5 mm/h. scored under the rectangular pattern. While, the lower value of 2 mm/h was obtained under the square pattern. Sprinkler application rates must be known so that the irrigation durations needed to apply specific depths of water can accurately be determined. The application rate should be equal to or less than infiltration rate to avoid the runoff. Regarding this type of soil these values are considered acceptable, because they are less than the basic infiltration rate value.

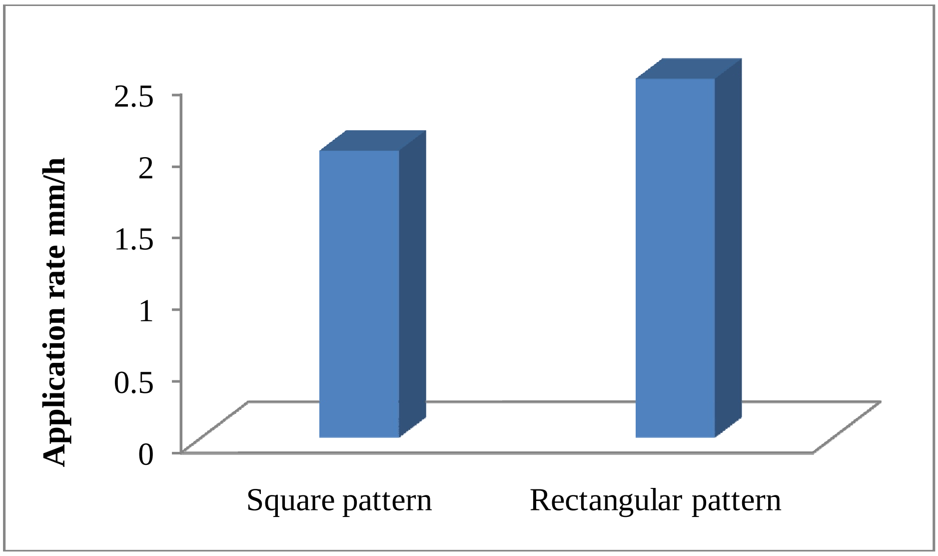

Fig. 4 Application rate of the two sprinkler patterns

The application efficiency was significantly affected by the two patterns. The highest value of application efficiency was 78% recorded under the rectangular pattern. While the lower value of 63% was obtained by the square pattern (Fig.5).These values are considered acceptable according to the application efficiencies reported by Evans *et al*. (1998). He stated that the solid set application efficiency ranges from 60 to 75 %.

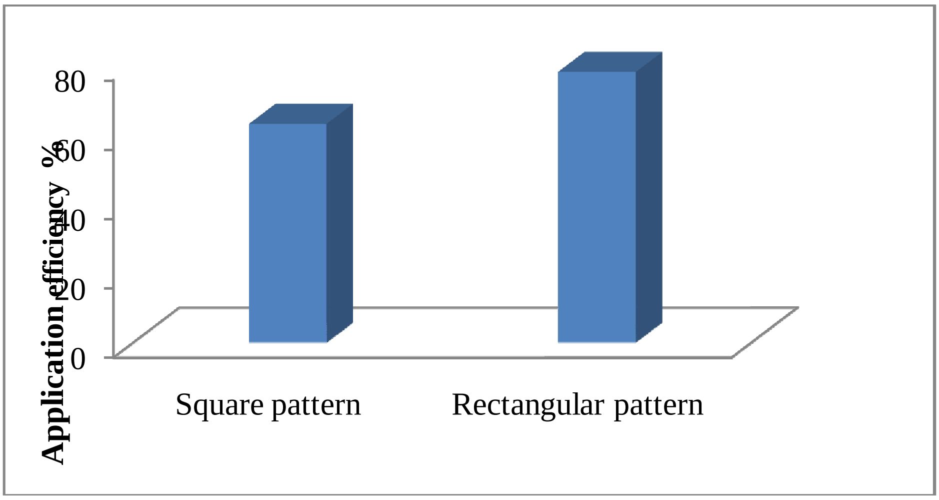

Fig.5. Application efficiency of the two sprinkler patterns

CONCLUSIONS

Semi portable solid set can apply the water efficiently and uniformly when it is properly installed, managed and maintained. Based on the results of this study the rectangular pattern performed better with respect to the uniformity, application rate and application efficiency when compared to the square pattern.

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تقييم أداء نظام الري بالرش شبه المتنقل jpj ظروف الخرطوم*

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مستخلص البحث: أجريت التجربة بمنطقة العليفون30 كيلو جنوب شرق الخرطوم على الضفة الشرقية للنيل الأزرق خلال موسم 2007 و 2008. كان الهدف تقييم أداء نظام الري بالرش شبه المتنقل عندما تم تركيبه على نمطين (أبعاد) هما مربع (18 متر × 18 متر) و مستطيل (12 متر × 18 متر). تصميم النجربة كان القطاعات الكاملة بثلاثة مكررات. تم تنفيذ إختبار أوعية التجميع لتحديد أداء الري المضاف بواسطة النظام شبه المتنقل.أيضاً تم تحديد إنتظامية التوزيع، معامل كريستيانسن، معدل الإضافة و كفاءة الإضافة. قيم إنتظامية التوزيع و معامل كريستيانسن للنمط المربع و النمط المستطيل كانت 63% ، 69% ، 70% و 75% ، على التوالي. معدل الإضافة و كفاءة الإضافة للنمط المربع و النمط المستطيل كان 2 ملم/ساعة ، 2.5 ملم/ساعة ، 63% و 78% على التوالي. ما يمكن تلخيصه هو أن النمط له أثر ملحوظ في أداء نظام الري بالرش شبه المتنقل، و عليه فإن النمط المستطيل حقق أعلى نتائج من النمط المربع.

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* جزء من اطروحة ماجستير قدمت بواسطة المؤلف الأول لجامعة الخرطوم

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