EFFECT OF OPERATING PRESSURE AND WATER QUALITY ON THE PERFORMANCE OF SOME SPRINKLERS

[1]E.M.Khalifa, [2]M.K.Elnemr, A.A.Elazaka

ABSTRACT

The main objective of this study is to evaluate the performance of different sprinkler types under two water qualities and four levels of operating pressure at ELREHAB city. For this purpose, three sprinkler types were selected and the operating parameters were evaluated. The results showed that for treated waste water (TWW) the best value of Christiansen Coefficient of Uniformity (CUC) and Distribution Uniformity (DU) were 86.83% and 78.11% respectively that was for (LPS) sprinkler at operating pressure 3.5 kP_a. And the results showed that for fresh water (FW) the best value of (CUC) and (DU) were 77.22% and 66.42 % at operating pressure 2.8 and 2.1 kP_a for (PS) and (PSU) sprinkler respectively. The analysis presented in this study may serve to develop a decision tool to choose the most suitable combinations of sprinkler model, nozzle diameter and working pressure to optimize the uniformity and efficiency of sprinkler irrigation.

Key words: *Christiansen Coefficient of Uniformity, Distribution Uniformity, treated waste water, fresh water, pop-up sprinkler.*

INTRODUCTION

In arid and semi-arid areas, irrigation is necessary for crop production because little or no rainfall occurs during the growing season. Types of irrigation methods commonly used are surface irrigation (furrow, border, basin), sprinkler irrigation (periodic-move, solid-set, continuous-move), and micro-irrigation (micro sprinklers, drip emitters, and drip tape) **(Hanson B. 2005)**.

The increase in water scarcity and wrong dimensioning of irrigation systems has threatened the viability and sustainability of agricultural production **(Khatri et al. 2013)**.

1. Agricultural Engineering Department, Faculty of Agriculture, Kafrelsheikh Univ.
2. Agricultural Engineering Department, Faculty of Agriculture, Damietta Univ.

Given this, irrigated agriculture, largest user of water in the world, has suffered social and economic pressure to mainly reduce water consumption. Thereby, improving the use of resources has become a challenge for irrigators who, by the necessity of prioritizing the application of water more accurately, need to know the main characteristics of the equipment to be used, to prepare them for better use in field conditions **(Martins et al. 2012)**.

The common index describing uniformity is the distribution uniformity (DU) defined as the ratio of the least amount of infiltrated water to the average amount (Hanson B. 2005). Without good uniformity, it is impossible to irrigate efficiently; parts of the field will be either over-irrigated or under-irrigated **(Haman et al. 2003)**.

Solomon (1998b) stated that the phrase 'irrigation uniformity' refers to the variation or non-uniformity in the amounts of water applied to locations within the wetted area. Uniformity is related to crop yields through the agronomic effects of under and over watering **(Griffiths and Lecler 2001)**. Sprinkler irrigation system performance is often evaluated based on uniformity coefficients from water collected in an array of measuring devices (catch cans).

Two methods have been developed to quantify uniformity, distribution uniformity (DU) and the coefficient of uniformity (CU) **(Baum et al. 2005)**. In sprinkler irrigation, water distribution figures for nozzles at different spatial arrangements are determined by considering the soaking field observed for each value of pressure and the size of nozzle. It is necessary that the determined water distribution be at an acceptable level.

This is determined by the equal distribution coefficient **(Allen. 2001)**. The aim of this work was to study the effect of operating pressure and water quality on the performance of some sprinklers.

MATERIALS AND METHODS

The experiment was conducted on ELREHAB city during 2015 winter season. For hydraulic studies of three different spray pop-up irrigation sprinklers separate experimental setup was made in open field. Christiansen Coefficient of Uniformity (CUC) and Distribution Uniformity (DU) were obtained by using the catch can method tests. Two water qualities were used first one was treated waste water (TWW) and the other one was fresh water (FW). The specifications of chemical and Bacteriological tests for (FW) and (TWW) showed in tables (2), (3), (4), (5), (6) and (7) respectively. The three spray pop-up sprinklers were Hunter PS Ultra (PSU), Hunter PS (PS) and Toro LPS (LPS). The experiment was conducted at four different operating pressures 2, 2.5, 3 and 3.5 kP_a for LPS and 1.7, 2.1, 2.4 and 2.7 kP_a for PSU and 1.7, 2.1, 2.4 and 2.8 kP_a for PS. A pressure regulator to regulate the pressure and a pressure gauge were used. Each nozzle size for all sprinkler types were (TVAN17).

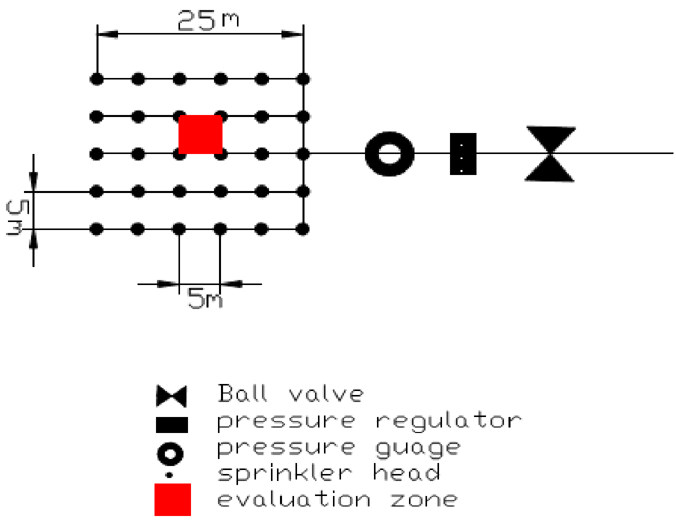

Fig. 1: Schematic diagram of sprinkler system network.

Table (1) Some characteristics for sprinklers

Specification of sprinklers			
commercial name	Hunter PS Ultra	Hunter PS	Toro LPS
Country made	USA	USA	USA
Sprinkler type	Spray pop-up	Spray pop-up	Spray pop-up
Sprinkler area (m^2)	5×5	5×5	5×5
Sprinkler model	PSU-04-4"	PS-04-4"	LPS400
Sprinkler symbol	PSU	PS	LPS
Nozzle type	TVAN17	TVAN17	TVAN17

Table (2) Organic chemical tests for FW

Test name	Sample ratio	The maximum allowed
C.O.D mg/l	0	0
B.O.D mg/l	0	0
NH_4 mg/l	0.15	0.5
NO_3 mg/l	0.19	45

Table (3) Inorganic chemical tests for FW

Test name	Sample ratio	The maximum allowed
pH mg/l	8.3	6.5-8.5
TS mg/l	301	—
TSS mg/l	10	—
TDS mg/l	291	1000
Cl^- mg/l	0.05	0.5 - 5
SO_4^{-2} mg/l	93	250
TH mg/l	245	500
Fe^{+2} mg/l	0.01	0.3
Zn^{+2} mg/l	0.03	0.4
DO mg/l	5.4	—
Ca^{++} mg/l	70	—
Mg^{++} mg/l	20	—

Table (4) Bacteriological tests for FW

Test name	Sample ratio	The maximum allowed
Total coliform bacteria (MF/100ml)	<1	Less than 1
Fecal streptococcus bacteria (MF/100ml)	<1	Less than 1
Fecal coliform bacteria(MF/100ml)	<1	Less than 1

Table (5) Chemical tests for TWW

Test name	Sample ratio	The maximum allowed
C.O.D mg/l	60	40
B.O.D mg/l	35	20
NH_4 mg/l	0.16	0.5
P mg/l	2.57	—

Table (6) Inorganic chemical tests for TWW

Test name	Sample ratio	The maximum allowed
pH mg/l	7.6	6-9
TSS mg/l	28	20
TDS mg/l	342	2000
Cl^- mg/l	0.7	0.5-5
SO_4^{-2} mg/l	65	300
Fe^{+2} mg/l	0. 128	5
Zn^{+2} mg/l	0.024	0.2
DO mg/l	4.04	More than 3
Ca^{++} mg/l	50	—
Mg^{++} mg/l	10	—

Table (7) Bacteriological tests for TWW

Test name	Sample ratio	The maximum allowed
Total coliform bacteria (MPN/100ml)	950×10^2	<5000
Ova of intestinal worms (number/liter)	<1	<1

The precipitation depth in catch cans placed at grid of 5×5 m and the distance between each can was 1 m spacing for all pop-up sprinkler types were considered. The average depth of water collected at each sampling point was recorded.

Uniformity of water application with sprinkler irrigation systems is usually reported as either the distribution uniformity (DU) or Christiansen's uniformity coefficient (CUC).

The coefficient of uniformity was computed using the Christiansen's equation (Allen, 1993) as:

$$\mathbf{CU = 100\left[1 - \frac{\Sigma X}{mn}\right]}$$

Where,

m = Average value of all observations (average application rate), mm

n = Total number of observation points.

x = Numerical deviation of individual observation from average application rate, mm.

Christiansen's coefficient tells us the average deviation across the field. A CU of 100% is perfectly uniform. A CU of 90% indicates an average deviation of 10%, etc.

The distribution uniformity (DU) emphasizes under-watered areas and compares the driest quarter of the field to the rest (Merriam and Keller.1978).The equation below was used to obtain the distribution uniformity:

$$\mathbf{D_u = \frac{d}{\bar{x}} \times 100}$$

Where,

D_u = distribution uniformity (%),

d = the lowest quarter irrigation volume applied in catch cans,

$\bar{x}$ = and the average volume applied in all catch cans.

RESULTS AND DISCUSSION

1- CUC

The results of (CUC) for the three pop-up sprinklers were obtained in table (8). As reflected in this table, results showed the highest values of (CUC) under TWW for (LPS), (PSU) and (PS) sprinkler types were 86.83%, 82.61% and 83.89% at operating pressure values 3.5, 2.4 and 2.4 kP_a respectively. While the lowest values of (CUC) were 71.99 %, 59.25 % and 65.23% for (LPS), (PSU) and (PS) sprinkler types at operating pressure values 2, 1.7 and 1.7 kP_a respectively.

Table (8) Christiansen's uniformity coefficient (CUC) values under TWW and FW.

Sprinkler name	LPS				PSU				PS			
operating pressure(kP_a)	2	2.5	3	3.5	1.7	2.1	2.4	2.7	1.7	2.1	2.4	2.8
CUC % for TWW	71.99	83.41	86.43	86.83	59.25	77.12	82.61	79.25	65.23	79.59	83.89	80.99
CUC% for FW	58.24	70.34	75.31	72.79	49.48	73.71	70.11	76.85	55	67.78	71.36	77.22

And for FW the results of (CUC) indicated that the highest values for (LPS), (PSU) and (PS) sprinkler types were 75.31%, 76.85% and 77.22% at operating pressure values 3, 2.7 and 2.8 kP_a respectively while the lowest values of (CUC) were 58.24 %, 49.47 % and 55% for (LPS), (PSU) and (PS) sprinkler types at operating pressure values 2, 1.7 and 1.7

kP_a respectively. Tarjuelo et al. (1999) reported that CUC should be more than 84%. If it taken into consideration, the (LPS) sprinkler type was the best one under TWW at the operating pressure value 3.5 kP_a. Low values of CUC for (PS) sprinkler type may be due to the climatic conditions prevailing in the day of measurement. This is may be due to the high wind speed during the test runs as presented in table (11). The obtained results agreed with Demirel and Sener (2007).

2- DU

The low-quarter distribution uniformities (DU) can be classified by the overall system quality ratings published by the Irrigation Association. The results of (DU) for the three pop-up sprinklers were obtained in table (9). The results showed the highest values of (DU) under TWW for (LPS), (PSU) and (PS) sprinkler types were 78.11%, 73.34% and 74.25% at operating pressure values 3.5, 2.4 and 2.8 kP_a respectively. While the lowest values of (DU) were 57.40 %, 42.55 % and 48.42% for (LPS), (PSU) and (PS) sprinkler types at operating pressure values 2, 1.7 and 1.7 kP_a respectively.

Table (9) Distribution uniformity (DU) values under TWW and FW.

Sprinkler name	LPS				PSU				PS			
operating pressure(kP_a)	2	2.5	3	3.5	1.7	2.1	2.4	2.7	1.7	2.1	2.4	2.8
DU % for TWW	57.4	71.63	77.14	78.11	42.56	65.12	73.34	68.12	48.42	64.97	71.49	74.26
DU% for FW	44.15	59.41	63.25	60.68	38.24	66.42	60.17	62.83	40.62	51.32	61.23	62.81

And for FW the results of (DU) indicated that the highest values for (LPS), (PSU) and (PS) sprinkler types were 63.24%, 66.42% and 62.80% at operating pressure values 3, 2.1 and 2.8 kP_a respectively while the lowest values of (CUC) were 44.14 %, 38.24 % and 40.62% for (LPS), (PSU) and (PS) sprinkler types at operating pressure head 2, 1.7 and 1.7 kP_a respectively. The lowest uniformity values of pop-up sprinkler systems tested in this work would be considered in the “fair” (50–59.9) to “poor” (40–49.9) range. This classification agreed with Siosemarde et al. (2012). Low values of DU for (PS) sprinkler type under FW as presented in table (9) may be due to the climatic conditions prevailing in the day of measurement. This is may be due to the high wind speed and low relative humidity during the test runs as shown in table (13).The obtained results agreed with Demirel and Sener (2007). According to the results, the most suitable pressure was 3.5 kP_a for (LPS) sprinkler type. The most suitable pressure for (PSU) was 2.7 kP_a and 2.8 kP_a for (PS).

These results were obtained when there was low wind speed (12.95 Km sec^{-1}). For this reason, if the wind speed exceeds the suggested limit, wider spacing than that used should be avoided.

Table (10) Climate data for the experiments under TWW.

sprinkler type	LPS				PSU				PS			
operating pressure(kP_a)	2	2.5	3	3.5	1.7	2.1	2.4	2.7	1.7	2.1	2.4	2.8
RH (%)	53	42	40	40	16	16	16	17	50	61	61	52
WS (Km/h)	undetected	9.25	12.95	12.95	14.8	14.8	14.8	18.5	undetected	7.4	7.4	12.95
T (°C)	20.8	22.8	22.6	22.6	24.5	24.4	24.4	23.4	19.5	16.6	16.6	17.8

WS: wind speed. RH: relative humidity. T: temperature.

Table (11) Climate data for the experiments under FW.

sprinkler type	LPS				PSU				PS			
operating pressure(kP_a)	2	2.5	3	3.5	1.7	2.1	2.4	2.7	1.7	2.1	2.4	2.8
RH (%)	47	46	48	48	27	35	27	27	21	21	21	28
WS (Km/h)	29.6	27.75	25.9	25.9	14.8	20.35	18.5	18.5	27.75	29.6	29.6	22.2
T (°C)	19.2	19.6	18.4	18.4	26.4	24.8	26	26	27.8	26.8	26.8	25

WS: wind speed. RH: relative humidity. T: temperature.

CONCLUSION

The aim of this research was to assess the performance of different sprinkler types under the effect of water quality and operating pressure.

It was observed that water quality has not a significant effect on CUC and DU values. The sprinkler type and operating pressure had a significant effect on CUC and DU. For this reason; irrigation application should be made under the appropriate operating pressure value for the suitable sprinkler. CUC and DU tables can also be used in given sprinkler layout to optimize irrigation management in response to the operating pressure.

These results could be used by irrigators to achieve the highest efficiency of sprinkler irrigation systems.

REFERENCES

Allen, R.G. (1993). Irrigation Engineering Principles. Department of Biological and Irrigation Engineering, Utah State University, Logan, Utah.

Allen, R.G. (2001). Catch3D Sprinkler Overlap Program and Sprinkmod. Department of Agricultural Engineering, Utah State University, Logan, Utah, USA.

Baum, M. C., M. D. Dukes, and G. L. Miller (2005). Analysis of residential irrigation distribution uniformity. J. Irrig. Drain. Engng. ASCE 131:336-341.

Demirel, K., and S.Sener (2009). Performance of Sprinkler Irrigation Systems at Different Pressures and Under Varying Wind Speed Conditions in Landscape Areas. Phillipp Agric Scientist. 92(3):308-314.

Griffiths, B. and N.Lecler(2001). Irrigation system evaluation. Proc. S. Afr. Sug. Technol. Ass. 75:58-67.

Haman, D.Z., A.G. Smajstrla, and D. J. Pitts (2003). Uniformity of Sprinkler and Microirrigation Systems for Nurseries. Florida Cooperative Extension Service University of Florida, BUL321.

Hanson, B. (2005). Irrigation system design and management: implications for efficient nutrient use. Western Nutrient Management Conference, Salt Lake City, UT, 6:38-45.

Khatri, K.L., A.A. Memon, Y.Shaik, A.F.H.Pathan, S.A.Shah, K.K.Pinjani, R.Soomro, R.Smith, and Z.Almani (2013). Real-Time Modeling and Optimization for Water and Energy Efficient Surface Irrigation. Journal of Water Resource and Protection, 5, 681-688.

Martins, P.E.S., E.R. da Silva, and J.R. Zanini (2012). Irrigação e suas interações com os atributos físicos do solo. In: Fernandes, C., Ed., Tópicos em física do solo, Funep, Jaboticabal, 88-106.

Merriam, J.L. and J. Keller (1978). Farm Irrigation System Evaluation: A Guide for Management. Department of Agricultural and Irrigation Engineering, Utah State University, Logan.

Siosemarde, M., M. Byzedi, and D.A. Nodehi (2012). The evaluation of water distribution uniformity in solid set sprinkler systems. Journal of Food, Agriculture & Environment,10 (2): 818-822.

Solomon, K.H. (1998b). The Economics of Uniformity. ITRC, California Polytechnic University, San Luis Obispo, California, USA.

Tarjuelo, J.M., J.Montero, F.T. Honrubia, J.J. Ortiz, and J.F. Ortega (1999). Analysis of uniformity of sprinkler irrigation in semi-arid area. Agric. Water Manage.40:315-331.

الملخص العربى

تأثير جودة المياه وضغط التشغيل على اداء بعض الرشاشات

السعيد محمد خليفة* ، معتز كمال النمر، احمد عباس العزقة**

أجريت تجربة حقلية في مدينة الرحاب في موسم الشتاء لعام ٢٠١٥ لتقييم اداء بعض الرشاشات تحت مياه مختلفة الجودة (مياه الصرف الصحي المعالج ، مياه رى عادية) وقيم مختلفة من ضغوط التشغيل لدراسة العوامل المؤثرة علي انتظام توزيع المياه وتشمل الدراسة أيضا اختيار أنسب أنواع الرشاشات التي يمكن أن تستخدم لتصميم نظام الري بالرش. كانت أنواع الرشاشات هى هنتر PS الترا ، هنتر PS، تورو LPS وقد شملت الدراسة قياس كل من معامل كريستيانسن للانتظامية (CUC)، انتظامية التوزيع (DU) وتم استخدام طريقة علب التجميع لتحديد تلك القياسات . وقد اعطت نتائج التجربة تحت تأثير مياه الصرف الصحى المعالج افضل قيمة لكلا من معامل الانتظامية وانتظامية التوزيع للرشاش LPS حيث كانت ٨٦.٨٣% و ٧٨.١١% عند ضغط تشغيل ٣.٥ كيلو باسكال على التوالى. وبالنسبة للنتائج تحت تأثير مياه الرى العادية كانت افضل قيمة لكلا من معامل الانتظامية وانتظامية التوزيع للرشاشPS وPSU حيث كانت ٧٧.٢٢% و ٦٦.٤٢% عند ضغط تشغيل ٢.٨ و ٢.١كيلو باسكال على التوالى.واوضحت النتائج ايضا ان جودة المياه ليس لها تأثير هام على قيم معامل الانتظامية وانتظامية التوزيع وان ضغط التشغيل له تأثير ملحوظ على قيم تلك القياسات.وان افضل ضغط تشغيل للرشاش LPSهو ٣.٥ كيلو باسكال وافضل ضغط تشغيل للرشاش PSUهو ٢.٧ كيلو باسكال وللرشاش PS هو ٢.٨ كيلو باسكال.

***قسم الهندسة الزراعية- كلية الزراعة- جامعة كفر الشيخ.**
****قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط.**