Evaluation of the hydraulic efficiency of the sprinkler irrigation

ABSTRACT

Aims: The research describes the methods of conducting some field studies to evaluate the effectiveness of sprinkler irrigation systems and to design them reliably. Also, the distribution of discharge in the irrigation system across the territory and its losses are analyzed.
Study Design: Christiansen's coefficient of similarity "CU" is used to estimate sprinkler water distribution.
Place and Duration of Study: Department of the “Hydraulics and hydroinformtaics”, “Irrigation and melioration”“Tashkent institute of the irrigation and agricultural mechanization engineers” National research university,between June 2021 and July 2022
Methodology: Christiansen's coefficient of similarity "CU"is carried out by studying three types of combinations according to the Catch Can method: sprinkler height, sprinkler discharge and pressure changes. In order to determine the Christiansen coefficient, it is calculated using the sum of experiments in taking into account the distribution of discharge according to the height of the sprinkler at several different pressures. Based on the method given above, the optimal height was determined in the assessment of water distribution. Based on field experiments and their analysis, a graph was created based on sprinkler height and flow distribution for discharge.
Results: Kindly make sure to include relevant statistics here, such as optimal height of the sprinkler chosen from three types of them including 0.5m, 0.75m, 1m. Above them 0.75 m is chosen as an optimal height of the sprinkler. As a result, correlation coefficient is a best one according to the pressure head (10m, 12m, 14m, 16m, 18m, 20m) and sprinkler height (0.5m, 0.75m, 1m) and water distribution (between 11m and 16m).
Conclusion: From the resultwe can use to calculate water distribution of sprinkler system in the 0.75 m height of sprinkler in the different pressure head. It also good for design and doing hydraulic calculation of this system.

Keywords:Water distribution, discharge, sprinkler system, pressure head.

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Comment [SG2]: 0.75m and 1m. Use “and” before the last data in other values

1. INTRODUCTION

In the context of climate change and increasing water scarcity, the introduction of resource-saving irrigation technologies in agriculture is of great importance. The purpose of this work is to evaluate the effective distribution of moisture in the sprinkler irrigation system. When choosing an irrigation method, it is effective to choose a method that can evenly distribute moisture to the field. For this, several indicators of the field should be taken into account: characteristics of the soil, topographic condition, available water source, groundwater condition, soil salinity, wind speed and direction. The main goal of any irrigation method is to evenly distribute water to the soil. A sprinkler irrigation system was chosen according to the above indications and the Catch Can method was used to study its effectiveness. The distribution of the amount of water coming out of the sprinkler irrigation system was evaluated using Christiansen's coefficient of uniformity. For this purpose, several tens of experiments were conducted by measuring the flow of water coming out of the sprinkler and its distribution at different pressures, and the result was obtained by the following formula [1,12]

$$Cu = 100\ (1 - \frac{\Sigma a}{m*n}) \quad (\%) \qquad (1)$$

Here, Cu is Christiansen's homogeneity coefficient, %; m-average value; a-amount of deviation from the average value; n is the number of trials. Various studies have been conducted to determine the effectiveness of the distribution of the amount of water coming out of the sprinkler. According to the article [12], at 6 different pressures (100-200), kPa was changed every 50kPa, and at 3 different sprinkler heights of 0.5 m, 0.7 m, 1 m, and the distribution of the amount of water coming out of two different nozzles was tested in experiments, and achieved good results. Another literature [5] emphasized that the correct choice of sprinkler height, pressure and diameter is very important for the efficiency of the system and reviewed with several experiments. In addition, [6] stated that the correct implementation of the distribution of the sprinkler irrigation system is the only and main way to increase its efficiency and conducted several experiments. From the experience of source [7] we can see the table above. According to it, Cu was calculated at 3 different heights of 0.3m, 0.6m, and 0.75m at the same pressure at 104kPa, and as a result, 88% uniformity was achieved at a height of 0.75m. As you can see, sprinkler height is also important in ensuring uniformity. According to the section "Sprinkler Irrigation" [8], as a result of research, it has been proven that the height of the sprinkler has an effect not only on "Cu", but also on the amount of water coming out of the sprinkler. According to the source study [9], Cu was calculated at heights of 50 cm, 100 cm and 150 cm at pressures of 138 kPa, 172 kPa and 207 kPa. As a result, at a sprinkler height of 50 cm, at a pressure of 172 kPa, it was equal to 96% Cu. According to the source [10], 83%, 85% and 88% of Cu were achieved by performing the Catch can experiment at a pressure of 104kPa at sprinkler height of 30cm, 60cm and 75cm. [11] calculated Cu at a pressure of 103kPa for sprinkler type (fixed and rotary) and nozzle diameters (5.6mm, 6.9mm) and found 90% Cu for 6.9mm and 80% Cu for 5.6mm. Various problems arise as a result of not fully studying the sprinkler irrigation system and not properly implementing the system project [16]. For this reason, the use of this method in irrigation and the problem of falling

efficiency of the sprinkler irrigation system are increasing [18]. One of the problems is the non-uniform distribution of water, that is, the consumption of water in parts of the area where water is not needed, and the release of large amounts of water as a result of increased pressure. One of the main reasons for these problems is the wrong choice of sprinkler type, errors in the distribution of pressure and water consumption, and the effect of sprinkler height is considered very important [17,20]. To find out the degree of distribution of water, using the Catch can method, (Cu) is estimated by the formula for calculating the coefficient of uniformity of Christiansen (1). To ensure uniform distribution of water in the sprinkler irrigation system, the amount of Cu should be more than 80%. The main purpose of this experiment and calculations is to determine the connections and values between the diameter of the sprinkler, its height and the pressure, consumption, and to estimate the distribution of the water coming out of the sprinkler by the Christiansen uniformity coefficient Cu.

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2. MATERIAL AND METHODS

For the experiment, several containers were installed around the sprinkler to determine the amount of distributed water. According to the above distribution method, having a CU value of more than 80% indicates a high degree of uniformity of the output water quantity. In the amount of less than 80% of CU, the uniformity is not satisfactory. The Catch Can method uses several containers to estimate water distribution. Containers are placed at the same distance around the sprinklers, and one container is placed on each side. The more dishes there are, the more accurate the calculations will be.

a) b)

Figure 1. a) sprinkler location: 1-container, 2-sprinkler; b) location of containers

The experiment was conducted using 3 different heights: 0.5m, 0.75m and 1m. There are 3 different 12 m. water column, 15 m. water column and 18 m. water column pressures were used. 32 of the containers were needed and its height was 118 mm, diameter was 80 mm. Containers are installed radially on sprinklers. In the experiments, the sprinkler was turned on and off at intervals of 45 minutes to one hour, and the pressure and water collected in the tank and time were measured and placed in a table. A sprinkler system is installed and its working principle is as follows: the pool is filled with nearby water sources and is calmed according to its quality; the water pump is turned on for a few minutes

until the flow is stable; the water goes to the main pipe and then reaches the sprinkler and the water is sprayed over the soil and the plant

Estimation of Christiansen's coefficient of uniformity (Cu). Christiansen's uniformity coefficient "Cu" is used to determine the irrigation efficiency, so the result of the Catch can method was evaluated using Cu [1]. The amount of deviation from the average value "a" in each container was determined as follows [14,12]:

$$a = V_i - m; m = \sum \frac{V_i}{n} \qquad (2)$$

Here, V_i is the measured volume of water in each container; m- average value; n is the number of trials.

3. RESULTS AND DISCUSSION

During the experiment, the flow distribution of the effective sprinkler type at different heights (0.5 m, 0.75 m, 1 m) and pressure changes (12 m. water column, 15 m. water column, 18 m. water column) was studied.

Table 1. The result of changes in the distribution diameter and uniformity coefficient due to pressure changes at different heights of the sprinkler

Sprinkler head, h [m]	1	1	1	0.75	0.75	0.75	0.5	0.5	0.5
Pressure head, P [m suvustuni]	12	15	18	12	15	18	12	15	18
Water distribution, D [m]	11.04	11.2	11.84	11.6	12.6	14.0	14.2	14.4	14.9
Uniformity coefficient, Cu [%]	78.6	85.3	85.49	80.1	82.2	91.1	70.7	77.6	78.1

Table 2. Amount of discharge from the sprinkler in containers

1-row, ml	2-row, ml	3-row, ml	4-row, ml	5-row, ml	6-row, ml	7-row, ml	8-row, ml
20	50	40	35	20	20	30	25
25	60	55	45	45	20	40	25
25	50	40	50	50	25	25	20
125	150	125	130	125	230	70	100
195	***310***	***260***	***260***	***240***	***305***	***155***	***170***

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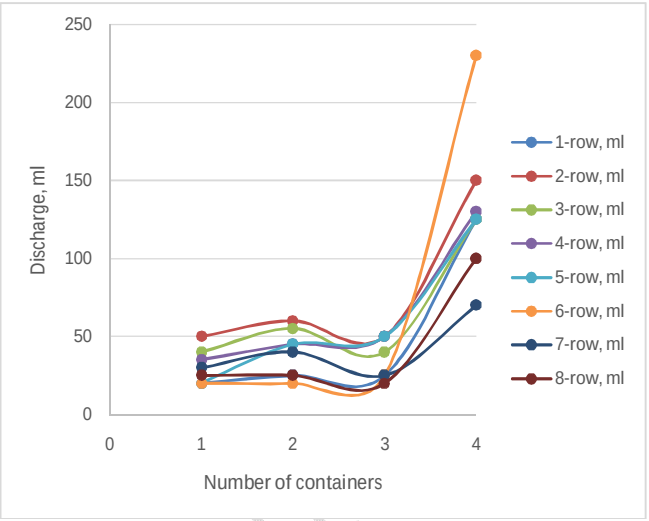

Figure 2. Graph of water distribution

At this stage, Cu values at different water pressures at 0.5m, 1m, 1.5m height are written in the following table:

Table 3. Variation of Cu value at different heights and pressure changes of sprinkler water distribution

Sprinkler head, h [m]	Pressure head, P [m suvustuni]	Uniformity coefficient, Cu [%]	The degree of uniformity
1	12	78.6	Average
1	15	85.3	Good
1	18	85.49	Good
0.75	12	80.1	Average
0.75	15	82.2	Average
0.75	18	91.1	Good
0.5	12	70.7	Stable
0.5	15	77.6	Average
0.5	18	78.0	Average

From the analysis of the conducted studies (Table 9), it became clear that the distribution of water consumption from the sprinkler [4,12] according to the source was equal to stable, average and good indicators. The maximum percentage indicator was seen in water consumption at 0.75m sprinkler height and 18m water column pressure. It shows that sprinkler height and pressure have an effect on its distribution.

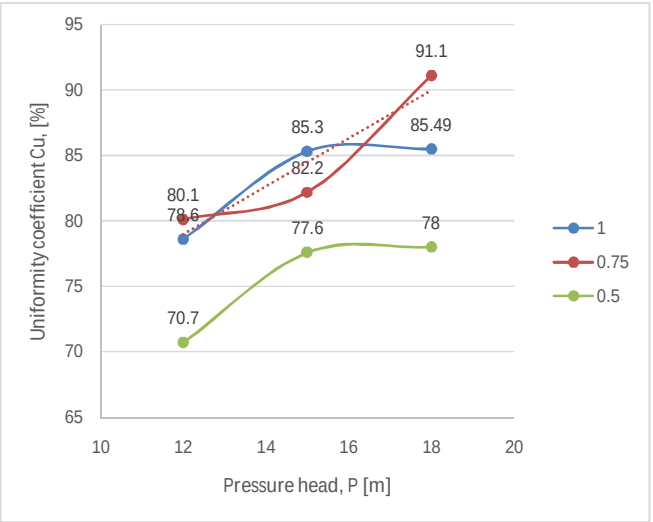

Figure 3. Variation of uniformity coefficient due to pressure and sprinkler height

Table 4. Water distribution of the sprinkler at different heights and pressures

Sprinkler head, h, [m]	Pressure head, P [m]	Water distribution length, D [m]
1	12	11.04
1	15	11.20
1	18	11.84
0.75	12	11.60
0.75	15	12.6
0.75	18	14
0.5	12	14.2
0.5	15	14.4
0.5	18	14.9

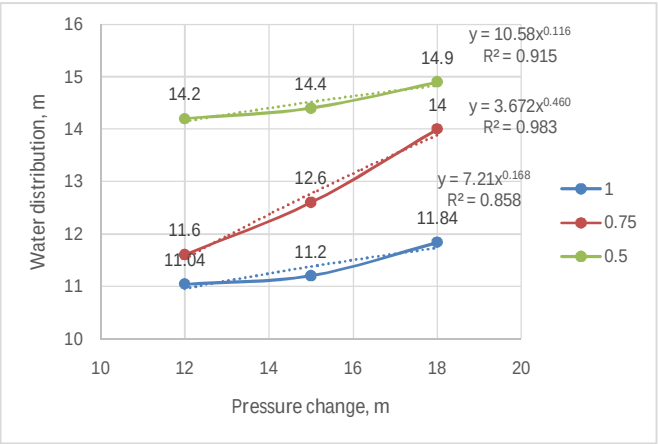

Figure 7. A graph of the length distribution of the sprinkler due to the height and pressure change

From the research analysis (Fig. 7), the following conclusions were reached regarding the change in the distribution diameter of water coming out of sprinklers at 3 different heights (0.5m, 0.75m, 1m) as a result of different pressure effects:

When the height of the sprinkler is 1 m, the pressure dependence of the water flow propagation length is expressed by the following relationship:

$$D = 10{,}58P^{0.11} \quad (3)$$

Based on the same analysis, the spread at a sprinkler height of 0.75 m:

$$D = 3.67P^{0.46} \quad (4)$$

Distribution at 0.5 m sprinkler height:

$$D = 7.21P^{0.16} \quad (5)$$

Based on the statistical analysis of the data collected in the research, the water flow distribution was chosen as the highest (92.39%) equal to the sprinkler height of 0.75 m and accepted as follows:

$$D = 3.67P^{0.46} \quad (6)$$

It is possible to calculate the length of water spread during the pressure change at the sprinkler height of 0.75m using the defined relation (6).

4. CONCLUSION

The evaluation of the efficiency of the sprinkler irrigation system was carried out by determining the uniformity coefficient of Christiansen. According to him, the

Christiansen homogeneity coefficient of the sprinkler was found to be stable (65-75%), average (75-85%) and good (>85%) values. The researches were conducted according to the change of pressure in 12m, 15m and 18m water columns, the influence of flow distribution length and change of water consumption was considered. According to it, it was observed that when the pressure decreases, water consumption decreases by 30% for every 2m of water column pressure and the diameter of the shot decreases by 10%. Also, it was found that changing the height of the sprinkler has an effect on the water consumption and the diameter of the shot. According to the results of the experiment, it was found that the greater the height of the sprinkler, the lower the flow distribution due to pressure, i.e., the pressure of each 2 m water column varies by 35%. At 0.5 m sprinkler height and 12 m water column pressure, the shot diameter was equal to 14.2 m, while at 1 m sprinkler height, this indicator was equal to 11.04 m. At the same time, at a sprinkler height of 0.75m and a water column pressure of 12m, the diameter of the shot was equal to 11.6m. As a result of the research, the collected data were analyzed based on mathematical statistics methods (Correlation coefficient R=0.95) and a relationship was obtained that evaluates the influence of water pressure on the length of the water flow.

REFERENCES

[1] Aderhold J, Davydov V Yu, Fedler F, Klausing H, Mistele D, Rotter T, Semchinova O, Stemmer J and Graul J 2001 *J. Cryst. Growth* **222** 701

[2] Keller J, Bliesner R D. Sprinkler and trickle irrigation. An Avi Book Van Nostrand Reinhold Pun, New York, 2015; p.651.

[3] Winward T., Hill R. "Catch-can performance under a line-source sprinkler Transactions of the ASABE (2017) 50(4) 1167-1175;

[4] Huang Y., Zhao H., Jiang Y., et al. "Comparison and analysis of different discrete methods and entropy-based methods in rain gauge network design" Water Switzerland 2019;

[5] Sourell H., Faci J.M., "Performance of rotating spray plate sprinklers in Indoor experiments" Journal of irrigation and Drainage engineering, October 2013;

[6] Sulaymon, Solomon, K H. (2018). Irrigation systems and water application efficiencies. Centre for Irrigation Technology, Irrigation Notes;

[7] Shearer, M.N. 2019. Uniformity of Water Distribution from Sprinklers as It Is Related to the Application of Agricultural Chemicals, Water Storage Efficiency, Sprinkler System Capacity, and Power Requirements;

[8] Keller J, Bliesner RB, (2010) Sprinkler and Trickle Irrigation. Chapman & Hall, New York, 625;
Natural Resources Conservation Service (NRCS). 2013. National Engineering Handbook. Section15. Chapter 11, Sprinkle Irrigation;

[9] Susanawati L.D, Suharto. B, Design and Construction of Sprinkler Irrigation for Stabilizing Apple Crop in Dry Season 2014;

[10] Merriam J.L., J. Keller. (2013). Farm Irrigation System Evaluation: A Guide for Management. Department of Agricultural and Irrigation Engineering, Utah State University, Logan;
[11] Maroufpoor E., A. Faryabi, H. Ghamarnia and G. Y. Moshrefi. 2014. Evaluation of uniformity coefficients for sprinkler irrigation systems under different field conditions in Kurdistan province;
W., and Podmore,T.H. (2015) „Performance of stationary gun irrigation systems." J. Irrig. Drain. Eng. 75–87;
[13] Christiansen, J.E. 2013. Irrigation by Sprinkling. California Agricultural Experiment Station. Bulletin No. 670. Berkeley.
[14] Arifjanov, A., Xodjiyev, N., Jurayev, S., Kurbanov, K., Samiev, L. Increasing heat efficiency by changing the section area of the heat transfer pipelines (2020) IOP Conference Series: Materials Science and Engineering, 869 (4). DOI: 10.1088/1757-899X/869/4/042019
[15] Arifjanov, A., Rakhimov, Q., Samiev, L., Abduraimova, D., Apakhodjaeva, T. Hydraulic friction coefficient at hydraulic mixing movement in pressure pipelines (2020) Journal of Advanced Research in Dynamical and Control Systems, 12 (7 Special Issue), pp. 1332-1336. DOI: 10.5373/JARDCS/V12SP7/20202233
[16] Vallal Kannan, S. (2023): Mechanized sowing and sprinkler method of irrigation for summer irrigated blackgram. Madras Agricultural Journal 106, 7–9 p.
[17] Arifjanov A.M., Kaletova T., Abduraimova D.A., Samiev L.N., and Jalilova X.A. (2022): Evaluation of the hydraulic efficiency of the sprinkler irrigation system, A Arifjanov et al 2022 IOP Conf. Ser.: Earth Environ. Sci. 1112 012131

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