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ORIGINAL ARTICLE

EFFECT OF IRRIGATION UNIFORMITY VALUES ON WATER DEPTHS FOR CENTER PIVOT SPRINKLER IRRIGATION SYSTEM

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Abstract: A field experiments was carried out under the center pivot sprinkler irrigation system (valley) in a study loam texture soil in AL-Anbar governorate-36 AL-Jabal province located 15 km North-East of AL-Ramadi. The study aimed the evaluate performance of center pivot sprinkler irrigation system by knowing the effect of uniformity coefficient values in the low water depths. Percent of the device speed was calibrated with the low water depths, the relation was studied between the devise speed and uniformity coefficient, also between the irrigation uniformity and the operational of pressure. The study results showed the following: (i) The increase of Law water depths which decrease the device speed percent, the increase percent was about 300.87% and 143.48% when decreasing the speed percentage from 100% to 50% and 25%, respectively, (ii) The uniformity coefficient reached the maximum at 90.78 with 2 pound inch^{-2} operational pressure, and (iii) The value of irrigation uniformity did not change with the varying of device speed percentage at the constant operational pressure depended on this study (25 pound inch^{-2}).

***Keywords*:** Uniformity coefficient, Water depths, Center pivot sprinkler irrigation system,

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1. Introduction

Center pivot sprinkler irrigation is one of the reliable tools of rationalizing water use in agriculture, it includes the evaluation standards for the sprinkler irrigation system, the uniformity of water distribution and the system flexibility. Many hydraulic variables control the value of the standards previously mentioned. Like the operation pressure and water depth, this requires rational use of water and efficiently managing irrigation projects in order to increase the production of water unit not the ground; because the water in our area is the basis for agriculture. The methods of filed evaluation foe performance of irrigation system are used currently for processing the problem of water loss due to the use and distribution by the irrigation system inside the field which is one of the significant problems in the agricultural field that use the different irrigation system. Therefore, the performance evaluation of irrigation system is necessary for all field irrigation system not only the center pivot one. Field evaluation is the process of quantum analysis for any system based on measurement taken from the field under the condition and cases usually [Al-Ghobari (2006)] system evaluation means determining the performance properties for the system such as the coefficient uniformity factor on the irrigation area, the optimum operational pressure and water depth on that area the problem of water lack during has a great impact on the availability and rationalization of this water and thus on planning for local and national water resources.

Reality calls for taking procedures to rationalize water use and raise the water unit value in order to achieve agricultural development balance with population growth and the increasing demand for food,

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as the center pivot sprinkler irrigation system (CPSIS) provides high possibility of controlling water and achieving high uniformity which increases the water unit production and adds new area [AL-Mehmdy (2003)]. The uniformity of water distribution is one of the important parameters for the evaluation due to the inability of current irrigation system to provide water equally to all points of the field [Jajjo and Al-Zaidi (2010)].

To measure the uniformity of water distribution with (CPSIS), the values of uniformity coefficient should be known, which is found from the field calculation for water depths collected in the measuring cans located at constant distance within the spray area. The study conducted by Christiansen (1942) is of the first studies to the distribution of irrigation water regularity above soil surface and he described it by the following equation:

$$UC = 100 \times \left(1 - \frac{\sum Xi}{\sum Ri}\right) \quad (1)$$

where, ΣXi = Total absolute deviation of water depths from the overall average of these depths and

ΣRi = Total water depths reaching the ground.

AL-Mehmdy (2003) found a variation in the water depths add to the irrigation area from the (CPSIS) as a result of the correlation with the values of uniformity coefficient, he obtained a value of 89% of irrigation uniformity when operating the (CPSIS) at 30 pound inch^{-2} operational pressure. While Chairman (2000) mentioned that the value of uniformity coefficient in Portugal vary from 85% to 90%. AL-Mehmdy (2003) indicated that by the increase of operational pressure, the size of the water drops leaving the nozzles decrease, the spray circles get bigger at the nozzles interfere between each other leading to raise the value of irrigation uniformity. The size of water drops is large at the low operational pressures which leads to decrease the diameters of spray circles and avoid the interference between them leading to low uniformity coefficient in the field [Chirman (2000)]. While Hicham and Yassen (1992) confirmed that the increase of operational pressure diverges the water leaving the nozzles to soft particles whose water surface area at which the evaporated water and water losses increase causing low values of uniformity coefficient. AL-mehmdy (2003) found that the increase of operational pressure from 30 to 35 pound inch^{-2} led to low values of uniformity coefficient from 89% to 80.94%, respectively. Darko *et al.* (2017) emphasized that the best design of irrigation system would be when adding water to a measured depth over the soil and the operating pressure must be considered in the design of the system. This study is aimed to determine the properties of irrigation for the system and how to distribute the water and specify their depths and the optimum operational pressure. The efficiency of a sprinkler irrigation system, which needs to be improved in many areas of the world, both in terms of water management and water application [Kumar *et al.* (2016)], depends on the various water losses that take place from the sprinkler nozzle until the point that water reaches the root zone [Aladakatti *et al.* (2015)].

2. Materials and Methods

A field experiment was conducted under the center pivot sprinkler irrigation system type “valley” covered area 60 D in a sandy loom texture in AL-Anbar governorate - 36 AL-Jabal, located 15 Km north east AL-Ramadi for the period form 15/11/2019 to 15/12/2020 to study the effect of water distribution uniformity under the (CPSIS). Samples of soil were taken for the depths (0.0-0.10, 0.10-0.20, 0.20-0.30 m), analyzed in laboratory to determine some of their physical and chemical characteristics (Table 1) and a four arm center pivot sprinkler irrigation device with a length of 218.60 m (Table 2).

The device velocity was calibrated with the depths achieved from these velocities [Christiansen (1942)] by marking a straight line from the center of device till the end of its arm. Cylindrical cans (36 cans) with volume of 538.51 cm^3 for each, were put along the straight line and distanced by 6 m. The velocity for the device’s arm was set according to the timer indicator on the control panel, the process of the speed and achieved water depth were repeated 3 times for each starting from setting the timer on 5% to 100% at 25 pound inch^{-2} operational pressure. The water volumes were transformed into depths (Table 3) according to the following equation:

$$d = \frac{V}{A} \quad (2)$$

where, d = Achieved water depth (mm).

V = Water volume in the collecting cans (cm^3)

Table 1: Some physical and chemical properties for soil before the study with depth of 0.0-0.30m.

Property			Value	Unit
Bulk density	**Depth(m)**	0.0-0.10	1.29	**Meg m^{-3}**
		0.10-0.20	1.40	
		0.20-0.30	1.50	
Volumetric moisture at tension 1500 kpa			16.66	%
Volumetric moisture at tension 33 kpa			29.98	
Volumetric moisture at tension 0 kpa			37.00	
$EC_{1:1}$			6.20	ds.m^{-1}
$pH_{1:1}$			7.60	-
Calsic			277	gm.kg^{-1}
Organic matter			2.00	gm.kg^{-1}
Gypsum			520	gm.kg^{-1}
			560	
			620	
Relative distribution for soil particles volumes		Clay	130	gm.kg^{-1}
		Silt	090	
		Sand	780	
Class of soil texture			Sandy loam	

A = Cross-section area of the cylinder (cm^3).

Values of the uniformity coefficient were calculated based on the achieved water depths at different speeds for the device using Equation (1). The best operational pressure for the (CPSIS) was chosen when testing several operational pressure (15, 20, 25, 30, 35) pound inch^{-2} based on the values of uniformity coefficient for each operational pressure with three replicates.

3. Results and Discussion

3.1 Achieved water depths and percent of device speed

Fig. 1 showed the relationship between speed percent's of the device and the achieved water depths for the (CPSIS) at 25 pound inch^{-2} operational pressure. It was shown that the achieved water depths was 5.75 mm when the timer indicator for device percent's was 100%. The water depth gradually increased with the continuous reduction of speed, where the achieved water depths reached 14.00 and 23.05 mm at speed of 50% and 25%, respectively.

It refers to the inverse relationship between the

Table 2: Lengths of arms and their covered areas for center pivot sprinkler irrigation system type "valley".

Sequence of arms according to their position from center	Arm length (m)	Covered area (D.)
First	54.65	3.75
First and second	109.30	15.00
First, second and third	163.95	33.76
First, second, third and fourth	218.60	60.00

Table 3: Achieved water depths at different speed percentage for the system with operational pressure of 25 pound inch^{-2}.

No.	Percent of device speed (%)	Achieved water depth (mm)	Time for complete cycle (hour)
1	05	80.00	26.27
2	10	50.00	25.27
3	15	37.00	24.23
4	20	30.00	23.19
5	25	23.03	22.15
6	30	20.00	21.11
7	35	18.00	20.07
8	40	16.00	19.03
9	45	15.00	18.00
10	50	14.00	16.95
11	55	13.00	15.28
12	60	12.00	14.43
13	65	11.00	13.58
14	70	10.25	12.73
15	75	9.50	11.88
16	80	8.00	11.03
17	85	7.50	10.18
18	90	7.00	9.33
19	95	6.50	8.48
20	100	5.75	7.63

speed and the achieved water depth, as the depth is related to the device operation time (Table 4). This relationship might be attributed to the reduction of irrigation time [AL-Mehmdy (2003)], as when the timer indicator of the device is at 100%. This means that the device continuously rotates around its center and completely irrigate the 60 domain area around which the device rotates (Table 2) with a time of 7.63 hour. While at 50% of the device speed, the system completes the irrigation of the area with 16.95 hour and this, in turn, refers that the device moves 30 second every 1 minute and that's the reason behind the increase of achieved water depth for this type of sprinkler irrigation system used in the irrigation. The increase percents in the achieved depths were 300.87% and 143.48% when decreasing the speed percentage from 100% to 50% and 25%, respectively.

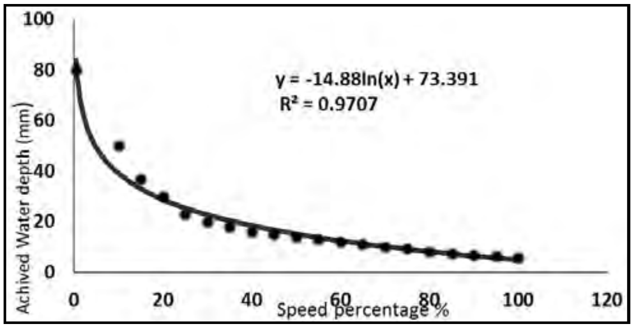

Fig. 1: Relationship between speed percent's and the achieved water depth at 25 pound $Inch^{-2}$ operational pressure

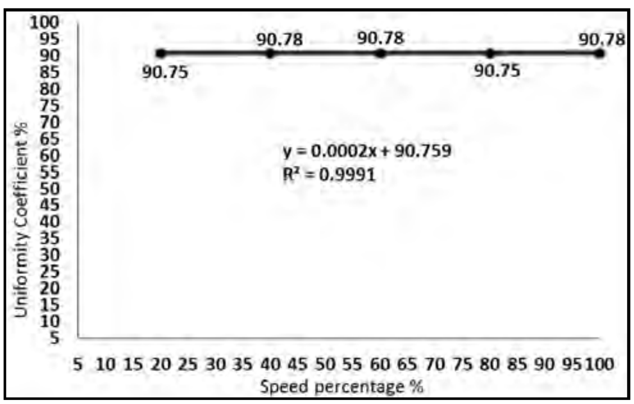

Fig. 2: Relationship between percent's of device speed and uniformity coefficient value at 25 pound $Inch^{-2}$ operational pressure

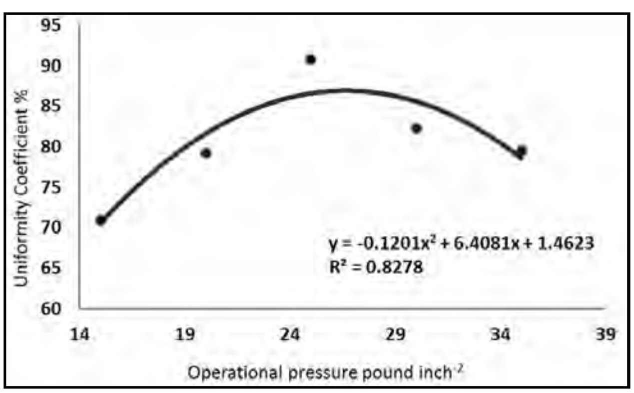

Fig. 3: Relationship between operation pressure and uniformity coefficient values

3.2 Uniformity of water distribution and device speed

Fig. 2 shows the relationship between the device speed and irrigation uniformity. It is observed from the figure that the values of irrigation uniformity ranged

Table 4: Achieved water depth rate and uniformity coefficient at 25 psi operational pressure for center pivot sprinkler irrigation system type "valley".

Achieved water depth (mm)	repe-tition	water depth* repetition (mm)	Devi-ation (mm)	Devi-ation *repe-tition
24.30	2	48.60	1.25	2.50
24.50	2	49.00	1.45	2.90
22.30	1	22.30	0.75	0.75
20.50	1	20.50	2.55	2.55
21.15	1	21.15	1.90	1.90
21.30	2	42.60	1.75	3.50
22.10	2	44.20	0.95	1.90
19.80	2	39.60	3.25	6.50
19.10	1	19.10	3.95	3.95
22.20	1	22.20	0.85	0.85
23.70	2	47.40	0.65	1.30
24.70	1	24.70	1.65	1.65
25.10	3	75.30	2.05	6.15
25.50	1	25.50	2.45	2.45
22.25	1	22.25	0.80	0.80
18.90	1	18.90	4.15	4.15
19.85	1	19.85	3.20	3.20
20.15	1	20.15	2.90	2.90
26.50	3	79.50	3.45	10.35
20.10	1	20.10	2.95	2.95
21.40	1	21.40	1.65	1.65
25.20	2	50.40	2.15	4.30
26.40	2	52.80	3.35	6.70
22.40	1	22.40	0.63	0.63
	N = 36 q = 829.90/36			
	q = 23.05 mm 76.48			
	q` = 2.124 mm			
Notes	UC = 90.78% $*UC = \left(1 - \frac{2.124}{23.03}\right)*10$			

from 90.75% to 90.78 % at speed percentage of 100% and 20%, respectively. It was also shown that the change in values of irrigation uniformity coefficient was so small (fewer than 0.03%), that the relationship between the two variables is linear. This change may be attributed to the conditions of calculation and to the vibration in tubes due to the variation in speed percentage at fixed operational pressure (25 pound inch^{-2}).

Operational pressure and irrigation uniformity

Fig. 3 shows the relationship between values of irrigation uniformity and operational pressure. It is observed from the figure that values of water distribution uniformity increased by the increase of operational pressure, as the irrigation uniformity reached 71.01% at operational pressure of 15 pound inch^{-2}, while it increased to 79.28% at 20 pound inch^{-2}. By continuing to increase the operational pressure to 25 pound inch^{-2}, the uniformity coefficient increased and reached the maximum value of 90.78%. This may be attributed to that by increasing the operational pressure, the size of water drops decrease and causing an increase in the diameters of spray circles that interfere between each other, which leads to raise the values of irrigation uniformity coefficient. This agrees with AL-mehmdy (2003) and AL-mehmdy (2015).

It is shown form Fig. 3 that the values of irrigation water uniformity again started to decrease at the increasing operational pressure for the systems they decreased to 82.32% and 79.55% by increasing operational pressure from 30 to 35 psi, respectively. This may be because of that the increasing of operational pressure caused the water particles to diverge into so small particles and evaporated water increase, causing a reduction in values of the water distribution uniformity and this agrees with that was mentioned by Hachem and Yassin (1992) and AL-mehmdy (2003) who achieved a decrease in uniformity coefficient by the increase of operational pressure to 35 psi.

4. Conclusions

- The achieved water depth increased by decreasing speed of the system.
- The maximum value of irrigation uniformity coefficient (90.78%) was achieved at the operation pressure of 25 psi.
- A small change of 0.03 % occurred in values of the irrigation uniformity coefficient due to varying speed of the system at fixed operational pressure of 25 psi.

Acknowledgements

Based on the data of this study, I recommend using an operational pressure of 25 psi in conditions similar to that of the study because it has obtained best value of uniformity coefficient and highest water depth that provide suitable moisture conditions.

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