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Impact Evaluation of Different Riser Heights on Uniformity Coefficient in Sprinkler Irrigation under Different Wind Speeds

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ABSTRACT

In this research, Christiansen's uniformity coefficient (CUC) was evaluated under different conditions of riser height, wind speed and sprinklers spacing. The results showed that in mild wind speed with increase of riser height CUC increased. Besides, by decrease of sprinklers spacing, CUC increased and with increasing of wind speed, CUC decreased.

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INTRODUCTION

The uniformity of water application in a sprinkler irrigation system is an important aspect of the system performance [28]. The performance of a sprinkler irrigation system is often evaluated based on water uniformity coefficients collected in an array of measuring devices (i.e. rain-gauge) [35]. Such system requires a minimum value of uniformity to be considered as acceptable by the end users [12]. The uniformity of the water distribution mainly depends on the spacing and arrangement of the sprinklers, the environmental conditions, the number and diameter of the nozzles, the sprinkler model and the operating pressure [5,14,24] and on the crop irrigated [31,32]. Playan *et al* [25] reported that the wind velocity is the meteorological variable most directly related to irrigation performance through its effects on Christiansen's uniformity coefficient (CUC) [6] and on the wind drift and evaporation losses (WDEL) [33]. Keller and Bliesner [14] classified the irrigation uniformity in solid set systems as "low" when CUC was below 84%. Little *et al* [18] suggested a classification of uniformity of a sprinkler irrigation system as very good, good, poor and worse if uniformity coefficient (CU) value equals 90%, between 80% to 89%, between 70% to 79% and < 69%, respectively. Merkley and Allen [23] considered CU>78% to be the minimum acceptable performance level for economic system design. Uniformity coefficient that developed by Christiansen [6] is stated below [40,20,3].

$$CU = 100\left(1 - \frac{\Sigma x}{n.m}\right) \quad (1)$$

Or

$$CU = 100\left(1 - \frac{\Sigma|z - m|}{\Sigma x}\right) \quad (2)$$

Where:
CU : distribution uniformity coefficient developed by Christiansen (%).
z : the amount of water measured in each container while testing uniformity (mm, ml).
x = |z-m| : the total absolute value of deviations from average of the amount of water measured in all accumulation containers (mm, ml).

$m = \frac{\Sigma z}{n}$: average amount of water (mm, ml).

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n : the number of water accumulation containers.

In practice, it‘s not possible to obtain 100% of uniformity on the irrigated area because nozzles distribute water on a circular area, with overlaps between areas of water distribution. It‘s impossible to have equal water distribution on the areas that are being irrigated [42,29]. Martinez *et al* [21] analyzed the influence of different design and performance factors, such as subunit arrangement, lateral spacing, working pressure, average application rate and application efficiency of water application cost, in a permanent set sprinkler irrigation system. The results showed that the most important factor was sprinkler spacing. Makki *et al* [22] reported that the twin nozzle brass sprinkler gave significantly better efficiency in comparison with twin nozzle plastic sprinkler and single nozzle plastic sprinkler. Stambouli *et al* [30] reported that sprinkler model has an important effect on the radial water distribution, even under similar operational conditions. Khodadadi Dehkordi [15] reported that with increase of nozzle-working pressure from 30 m to 50 m, CUC increased and the square layout had the most CUC and rectangle layout had the least of it. The main objective in this research is evaluation of uniformity coefficient of water distribution in different conditions of riser height, wind speed and sprinklers spacing.

MATERIALS AND METHODS

This study was conducted in an uncultivated farm that was located in North West of Shush County from Khuzestan province of Iran with tropical climate. A permanent sprinkler system was located in this farm. The water resource of this farm was provided from Karkheh River. Some weather parameters, in 3 months that experiment was done, are shown in Table 1.

Table 1: Some weather parameters of Shush County.

Month	(m) Elevation	Daily sunshine hours	Mean of min temperature (°C)	Mean of max temperature (°C)	Mean of humidity (%)	ET_0 (mm/d)
July	65	10.4	27.9	45.3	23	10.69
August	65	10.1	27.1	45.2	26	9.68
September	65	9.92	23.3	42.5	29	7.62

The sprinkler that was used in this plan was from kind of Zhaleh 3 that was made in Techno Zhaleh Company of Iran. It was twin-nozzle sprinkler with 9/32×1/8 inches diameters. The characteristics of Zhaleh 3 sprinkler with 9/32×1/8 inches diameters are presented in Table 2. For evaluation of uniformity coefficient of water distribution used from Christiansen equation. The experiment was done on base of a single working sprinkler method. For gathering of sprinklers water, a 3m×3m grid system of catch containers were located around Zhaleh 3 sprinkler (Figure 1). Every catch containers had 15cm diameters and 15cm height that were located into the ground, whereas their rims were 5cm above the ground surface. The nozzle-working pressure in this plan was 30 m and sprinklers arrangement style was square layout with sprinklers spacing of 15m×15m and 24m×24m. In this layout, the first space was sprinklers spacing on the laterals and the second space was laterals spacing on the main pipe. In addition, for measuring of wind speed used from four-cup-anemometer. For impact evaluation of wind speed on CUC used form three ranges of wind speeds (0-4 [mild], 4-7 [moderate] and 7-10 [severe] [m/s]). For impact evaluation of riser height on CUC used form three riser heights including 120 cm, 150 cm and 180 cm. For evaluation of CUC, the experiments in different riser heights and in different ranges of wind speed, were replicated three times and average of data was considered and presented in Tables. The time of working for every experimental sprinkler was 1 hour.

Table 2: The characteristics of Zhaleh 3 sprinkler with 9/32×1/8 inches diameters.

Working pressure (m)	Discharge (m^3/hr)	The wetted diameter (m)
32	4.01	41.5
35	4.21	42.1
39	4.41	42.7
42	4.60	43.6

RESULTS AND DISCUSSION

CUC in different conditions of wind speed, riser height and sprinklers spacing are presented in Table 3.

1- The first space (15m) is sprinklers spacing on the laterals and the second space (15m) is laterals spacing on the main pipe.

The impact evaluation of riser height on CUC:

Table 4 shows the effect of riser height on CUC. According to Table 4, the riser height had not any effect on CUC because CUC of the entire riser heights achieved about 84%.

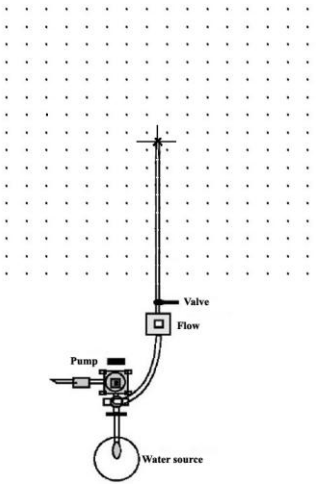

Fig. 1: 3m×3m grid system of catch containers around Zhaleh 3 sprinkler.

Table 3: CUC (%) in different conditions of wind speed, riser height and sprinklers spacing.

Wind speed (m/s)		Working pressure (m)	Riser height (cm)	Sprinklers Spacing (m)	
				Square 15×151	Square 24×24
Mild	0-4	30	120	92.44	82.45
	0-4	30	150	94.52	85.32
	0-4	30	180	97.73	87.61
Moderate	4-7	30	120	91.68	81.83
	4-7	30	150	91.43	81.25
	4-7	30	180	90.31	80.11
Severe	7-10	30	120	82.73	74.75
	7-10	30	150	80.41	72.32
	7-10	30	180	78.87	70.21

Table 4: The effect of riser height on CUC.

Riser height (cm)	CUC (%)
120	84.31
150	84.21
180	84.14

According to Table 3, in mild wind speed with increase of riser height from 120 cm to 180 cm, CUC increases. It may be for reducing of turbulent flow in riser entryway and increase in wetted area and pattern width with increasing of riser height. This result is confirmed by Ahmed *et al* [1]. Besides, in moderate wind speed the riser height had not any effect on CUC. However, in severe wind speed with increase of riser height from 120 cm to 180 cm, CUC decreases. Because in severe wind speed the negative effect of wind speed on CUC increases with increase of riser height. This result is confirmed by Al-Khafaf *et al* [2]. According to Table 3, CUC in riser height of 120 cm, in sprinklers spacing of 15×15 m and at mild wind speed is 92.44% that it decreases in severe wind speed to 82.73%, therefore it has been reduced 10.5%. But CUC in riser height of 180 cm, in sprinklers spacing of 15×15 m and at mild wind speed is 97.73% that it decreases in severe wind speed to 78.87%, therefore it has been reduced 19.3%. This is due to increase of the negative effect of severe wind speed on CUC with increase of riser height.

The impact evaluation of sprinklers spacing on CUC:

Table 5 shows the effect of sprinklers spacing on CUC.

Table 5: The effect of sprinklers spacing on CUC.

Parameters	Sprinklers spacing (m)	
	15×15	24×24
CUC (%)	88.90	79.54
The proportion of sprinklers spacing to wetted diameter of 44 m (in nozzle-pressure of 30 m)	0.34 × 0.34	0.55 × 0.55

According to Table 5, sprinklers spacing of 15m×15m had the most CUC (88.90%) and sprinklers spacing of 24m×24m had the least CUC (79.54%). Actually, by decrease of sprinklers spacing, CUC increases. This is because of better overlap of sprinklers spray in less sprinklers spacing. This result is confirmed by Khodadadi Dehkordi [15]; Kara *et al* [16]; Tarjuelo *et al* [37]; Joshi *et al* [13] and Sahoo *et al* [34]. For reducing of

sprinklers spacing, it is important to consider economic aspects in this subject. Actually, reducing of sprinklers spacing should be justifiable from economic aspects. In this research, the proportion of sprinklers spacing to wetted diameter for square layout was 0.34×0.34 (for sprinklers spacing of 15m×15m) and 0.55×0.55 (for sprinklers spacing of 24m×24m) at nozzle-pressure of 30 m. Christiansen [6] recommended the proportion of sprinklers spacing to wetted diameter: 0.4×0.6 for rectangle and 0.5 for square layouts. Besides, Keller [17] recommended the proportion of sprinklers spacing to wetted diameter: 0.5 for square, 0.4×0.67 for rectangle and 0.62 for triangle layouts. Khodadadi Dehkordi [15] recommended the proportion of sprinklers spacing to wetted diameter at nozzle-pressure of 50 m including: 0.29×0.29 (for sprinklers spacing of 15m×15m) and 0.46×0.46 (for sprinklers spacing of 24m×24m) for square layout and 0.40×0.29 (for sprinklers spacing of 21m×15m) for rectangle layout.

The impact evaluation of wind speed on CUC:

Table 6 shows the effect of wind speed on CUC.

Table 6: The effect of wind speed on CUC.

Wind speed (m/s)		CUC (%)
Mild	0-4	90.01
Moderate	4-7	86.1
Severe	7-10	76.55

In this research, CUC was measured in three ranges of wind speed. They were mild wind (0-4 m/s), moderate wind (4-7 m/s) and severe wind (7-10 m/s). According to Table 6, with increasing of wind speed, CUC decreases. This result is confirmed by Khodadadi Dehkordi [15]; Von Bernuth and Seginer [41]; Seginer *et al* [26]; Seginer *et al* [27]; Faci and Bercero [10]; Tarjuelo *et al* [36]; Tarjuelo *et al* [38]; Hans *et al* [11]; Li and Kawano [19]; Azevedo *et al* [4]; Urrutia [39]; De Lima *et al* [8] and Dechmi *et al* [9]. The most of these researchers confirms two results, first: applied water is lost partially by evaporation and especially it drifts out of the irrigated area, second: water distribution pattern in windy conditions is distorted. Besides, the effect of moderate wind speed on CUC is very less than severe wind speed. Because with increasing of wind speed from mild to moderate range, CUC 4.3 percent decreases but with increasing of wind speed from mild to severe range, CUC 14.95 percent decreases. According to Table 3, with decreasing of sprinklers spacing, the negative effect of wind speed on CUC decreases. Whereas, CUC of 15×15 m sprinklers spacing in 120 cm riser height and in severe wind speed is 82.73% but in 24×24 m sprinklers spacing is 74.75%. It is due to the decrease of sprinklers spacing in proportion to wetted diameter. This result is confirmed by Khodadadi Dehkordi [15]; Vories and Von Bernuth [40]; Cuenca [7] and Sahoo *et al* [34].

Conclusion:

The results showed that in mild wind speed with increase of riser height CUC increased. Besides, in moderate wind speed the riser height had not any effect on CUC and in severe wind speed with increase of riser height CUC decreased. In addition, the results showed that by decrease of sprinklers spacing CUC increased and with increasing of wind speed CUC decreased. Actually, the effect of moderate wind speed on CUC was very less than severe wind speed.

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