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EVALUATION OF SOME UNIFORMITY COEFFICIENTS FOR PRESSURIZED IRRIGATION SYSTEMS UNDER FIELD CONDITIONS IN DUHOK GOVERNORATE (IRAQI KURDISTAN)

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ABSTRACT

The study was conducted in May–October 2021 within the Duhok University, Iraq, the study was carried out on the land adjacent to the College of Agricultural Engineering Sciences, in the fields of the "Seajay" village latitude 36^0 55' 28''N, longitude 42^0 52' 36''E and 640 (m.a.s.l), the objective of the study was focus on evaluating different uniformity coefficients proposed on investigating the effects of run time and field conditions on the results obtained utilizing those coefficients, a layout of 144 m^2 was designed according to the length of lateral lines, 36 catch cans were positioned in a grid of 2 m apart. determining water distribution efficiency affected by different weather conditions during two- daily runs (morning &evening), and two time periods (May & June-July 2021) under operating pressures of (1.0 - 2.0) bar and riser heights of (1.0 - 2 m), solid site sprinkler with a single nozzle type (5mm) was used. The water caught in Cans was subjected to a three-way (ANOVA) table using (LSD) test, the study concluded that riser heights of 1 m had the optimum (CU & DU%) at 2 bar (operating pressure) to reduce water losses, and the results showed that highly significant differences between the means of (CU & DU%) coefficients in (May 2021) at various run times (morning & evening), in time it was shown highly significant differences between the means of all parameters with (PELQ %) coefficients in the (June –July 2021) period. It is not suggested to run the sprinkler irrigation system at wind speeds of (2.6 - 3.6 ms^{-1}).

KEYWORDS: Coefficient, evaporation, pressure, sprinkler, weather.

INTRODUCTION

In the past and the future, irrigation has been and will be essential to the growth of agriculture (FAO, 2000). In times of insufficient rainfall, it provides the water required for agricultural development. The demand for food production to feed a burgeoning population is driving a quick increase in irrigation. Surface irrigation is the primary irrigation technique used globally. When compared to pressurized systems like sprinkler and drip irrigation, the labor required for this technology is relatively significant. They have excellent efficiency, little water loss, and little labor requirements (Abdelmoneim et al., 2019). According to Michael (1978), it's critical to apply the correct amount of water to the field and distribute it evenly throughout. The uniformity of water distribution made possible by a particular soil and irrigation management technique greatly influences the acceptable lengths of irrigation runs.

A sprinkler system's water distribution application is richer and more cogent than a surface irrigation system (Yazar et al., 1999). In order to the cost of irrigation and water losses, it is necessary to enhance the way the sprinkler irrigation system operates (Okasha and Pibars, 2016; and Kincaid et al., 1996). Field test losses were reported by Kohl et al. (1987) and Yazar (1984) to range from 2 to 40% (usually 10 to 20%). In contrast, losses under a moderate evaporative state should not exceed 5 to 10 percent (Keller and Bliesner 1990). In addition to being a direct loss of water, droplet evaporation during spray irrigation has a substantial impact on microclimate. It improves the microclimate of the irrigated region by lowering temperature and vapor pressure deficit, which reduces transpiration and soil evaporation (Thompson et al., 1993). Evaporation losses are influenced by environmental parameters (air temperature, air friction, relative humidity, solar radiation, and wind speed) and equipment-related factors (nozzle size, angle, operating pressure, and height of the sprinkler). The evaporation losses were hardly impacted by operating pressure. Numerous studies have revealed that the width of the nozzle significantly impacted the droplet breakup and consequently affected the evaporation losses (Kohl and Wright 1974, Solomon et al., 1985). On the upwind side, this produces transient dry zones close to the sprinkler laterals. Wind can occasionally aid with uniformity, according to Merkley and Allen (2004), since the unpredictability of wind gusts and turbulence contributes to smoothing the profile of the distribution pattern. Tighter spacing is advised to reduce wind impacts depending on how strong the wind is. The effectiveness of a sprinkler irrigation system is frequently assessed using data from a variety of measurement tools, such as rain gauges, which measure water uniformity coefficients (Topak et al., 2005). According to some writers, the wind is the primary environmental factor influencing sprinkler effectiveness (Solomon 1979; Kincaid et al., 1996; Dechmi et al., 2003).

It is possible to consider the frequency distribution of the applied water to be a normal and uniform function (Anyoji and Wu 1994; Mantovani et al., 1995; Li 1998). The coefficient, which is a measurement of the absolute deviation from the mean divided by the mean, is generated from the catch can data based on the assumption that the catch cans reflect the same area. The objectives and Aims of the field study are to assess the pressurized irrigation system's efficiency in applying water and reducing water waste by examining the performance of the sprinkler irrigation system (solid-sets) in relation to weather conditions, riser height, and operating pressure.

MATERIAL AND METHODS

The study area is located within the Duhok University, Iraqi Kurdistan Region. It lies on latitude 36^0 55’ 978’’N and longitude 42^0 52’ 836’’E and 640 (m.a.s.l). The study was carried out on the land adjacent to the College of Agricultural Engineering Sciences, in the fields of the “Seajay” village Figure1.

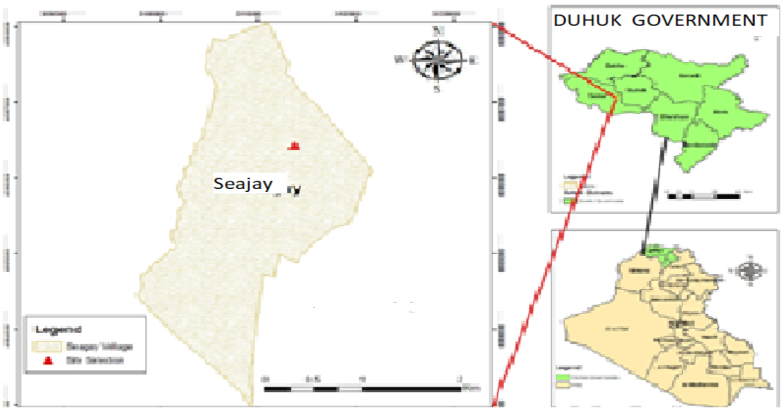

Fig. (1): The study area “Seajay village”

The annual maximum and minimum rainfall in the area range between (450 - 500 mm), the yearly maximum and minimum temperatures in the area are 41°C and 10.3 °C respectively. The field has an area of 144 m^2 (12 m * 12 m). The vegetation of the field was cleared and mapped out with pegs to form a grid as shown in Figure 2. The current study evaluates the coefficients of uniformity, distribution uniformity, and potential application of efficiency low quarter by measuring the water volume applied by different combinations of operating pressure, riser height, and test time. Two levels of operating pressure (1.0 and 2.0. bar), and two riser heights (1.0 and 2.0 m), with one sprinkler nozzle diameter (5.0 mm) applied, and all tests and Data collection were applied at two spans (Morning and Evening) at times periods (May and June –July 2021).

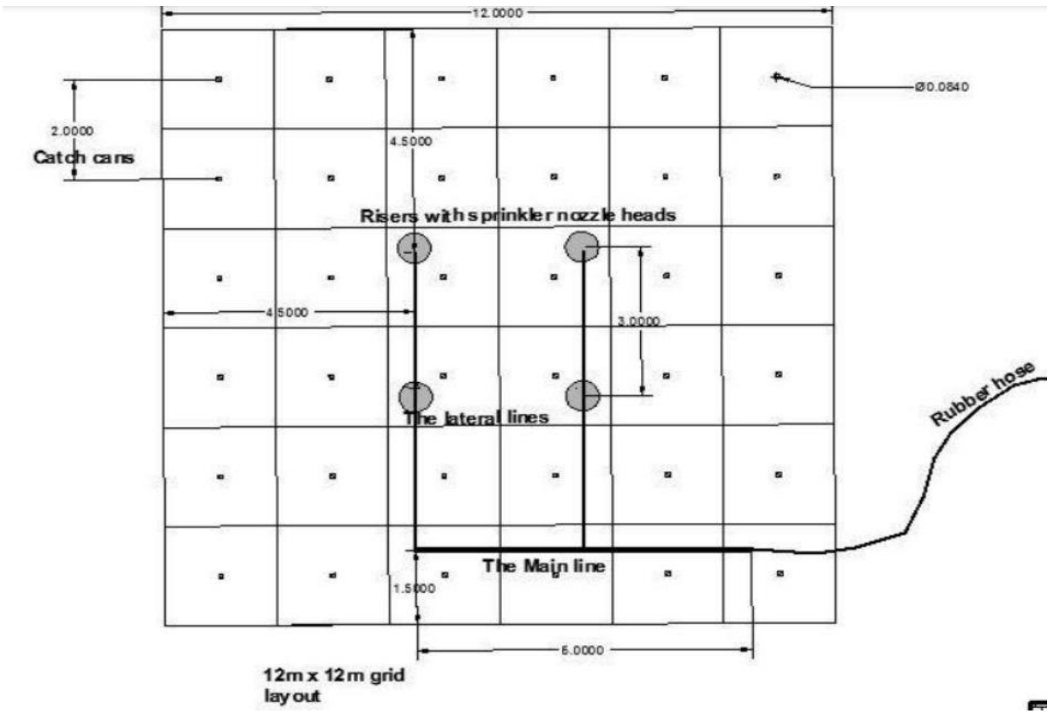

Fig. (2): The layout of the field experiment.

Experimental design and Statistical analysis:

The field experiment is (three Way) randomized completely block design (RCBD). The comparison between means will be carried out according to the LSD test using a computerized Microsoft Excel program.

The sprinkler irrigation system has about 20 m a mainline long with a 50 mm diameter. Two lateral lines have 25 mm diameter with 3 m long, pattern soled sits squared sprinkler irrigation $3*3m^2$, Figure2. The sprinkler irrigation system conveys water from the reservoir through the main and lateral line to the sprinkler nozzle which sprays the water in the form of rain to the field.

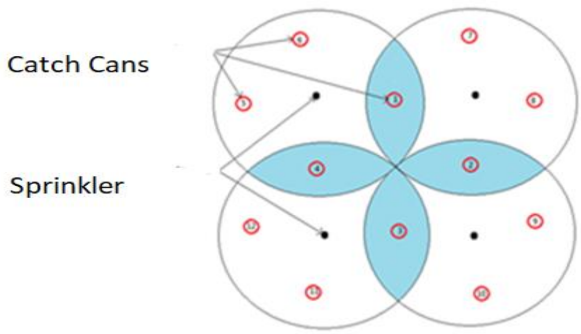

Fig. (3): Square pattern sprinkler irrigation system spacing.

The square pattern of the soled site sprinkler was used in the current study for irrigating testes the square-shaped regions because it has equal distances between the four sprinkler sites Figure3.

Fig. (4): Field experiment.

The solid sprinkler site sprays the water in the form of raindrops to the defined area. The characteristics and manufacturers details of the pressure gauge are in Figure 4. Spraying fixed on raisers (1&2 m height), nozzle diameter (5 mm), discharge of the four sprinklers (m^3/sec), sprinkler heads specifications consist of (pressure gauge bar), and operation capacity 360 full circles, the sources from (DELVE) company for trade irrigation and agriculturel.

The used equipment:

Water Pump: The water pump suctions the water from the "well" to the field study site.

It is used to measure the operating pressure of the sprinkler system by Pressure gauge instrument Figure 5.

Fig. (5): Pressure gauge instrument.

In the current study (36) Catch Cans were used to measure the collected water volume from four applied sprinklers, the diameter and height of the catch can be (114.5 and 100 mm) respectively, and the total volume is about (1000 Cm^3) capacity, the required water volume should be collected in the center catch cans as shown in previous research

Tape: A 50 m linen tape was used to measure the field borders layout, spacing of the catch cans, and wetted diameter.

Volumetric cylinder:

The cylinder was used to measure the water caught by the catch cans. It has a capacity of 500 cm^3, but a plastic cylinder with the same volume is more provable to prevent breaking.

The pitot instrument:

Pitot applies to measure sprinkler discharge by using the following formula

$$q=a*c\,(2*g*H)^{0.5} \quad ....(1)$$

where q is the water discharge from the single nozzle (m^3/sec).,

a, the area of the nozzle orifice in m^2

c, is Constance= 0.96.

g, and H are accelerated gravity (9.81) and head pressure in meter high respectively Figure 6.

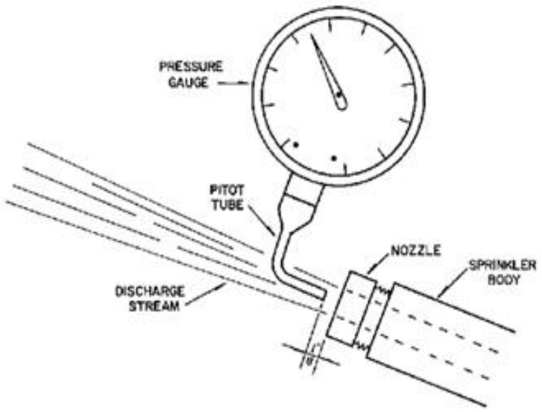

Fig. (6): The schedule of the pitot instrument.

Cup Anemometer:

A Cup anemometer was used to measure wind speed (ms^{-1}), and direction (Type **Casella**) in UK.

Psychrometer Portable (Dry-Wet) (Type Assmann):

It used of measure the temperature (C^o) and relative humidity (RH%). (Figure7.a &b)

a b

Fig. (7): Cup anemometer (a), psychrometer (b).

Weather station:

Computerized weather station attributed to Agricultural Engineering Sciences College. wind and direction, temperature, and relative humidity probes execution interval by a data logger (Type Davis) Figure 8.

Fig. (8): Automatic meteorological weather station.

Evaporation and drift losses in Sprinkler irrigation:

The optimum equation for forecasting the evaporation and drift losses from the sprinkler technique using field weather date and riser height (m) as a variable according to Abo-Ghobar (1994), as proposed by Drapper and Smith (1966):

E (%) = 4.506 - 0.518 Ln D + 0.703 LnH+0.137 Ln U-0.04 Ln RH +0.022 LnT.......... (2)

Where:

E= Evaporation and drift losses, (%).

D = Nozzle diameter, (m).

H = Riser height, (m).

U = Wind velocity, (km/h).

RH = Relative humidity, (%).

T = Air temperature, (°C).

Weather information:

As reported in Table1.a & b, meteorological data were acquired from the field weather station. Each test involved of, air temperature (°C), relative humidity (percent), Pan evaporation (mm/day), vapor pressure (kpa), wind speed (km/h), and direction during the study period (May and June-July, 2021).

Table (1): a Mean of weather information from the field weather station during the test times in May 2021.

Time	Test Run	Temperature (C^o)	Relative Humidity (%)	Evaporation Pan (mm/hr)	Vapour pressure (kpa)	Wind speed (m/sec)	Wind direction
	1	34.43	11.2	0.019	4.927	0.71	
Morning	2	30.00	23.06	0.033	4.53	0.22	NE
	3	32.06	15.1	0.053	2.75	1.07	
	4	25.00	28.2	0.031	2.28	2.18	SE
	1	34.80	13.76	0.034	4.856	1.43	
Evening	2	34.97	15.70	0.034	3.95	1.75	NE
	3	34.60	18.36	0.025	4.53	2.24	
	4	28.73	24.03	0.027	3.00	3.10	SE

Pressure: Riser=1:1, 2:1, 2:2, 1:2

Table (1): b Mean of weather information from the field weather station during the test times in (June & July 2021), 2021.

Time	Test Run	Temperature (C^o)	Relative Humidity (%)	Evaporation Pan(mm/hr)	Vapour pressure (kpa)	Wind speed (m/sec)	Wind direction
	1	33.66	16.06	0.036	4.39	0.75	
Morning	2	30.20	25.13	0.030	3.21	1.09	
	3	32.76	17.90	0.032	4.07	1.73	
	4	35.73	8.76	0.038	5.38	1.94	NW
Evening	1	37.66	17.10	0.042	5.71	2.15	
	2	37.43	12.10	0.040	5.66	3.49	
	3	38.83	8.90	0.063	6.35	2.86	
	4	26.83	9.30	0.035	5.87	1.93	

Pressure: Riser=1:1, 2:1, 2:2, 1:2

Methods of calculating some selected performance indicators including Christiansen uniformity (CU%), Distribution uniformity (DU%), and Potential efficiency of low quarter (PELQ%):

Christiansen coefficient of uniformity (1942) created the non-weighted (CU), which is represented as follows:

$$CU = 100\left(1 - \frac{\sum \left|x_i - \bar{x}\right|}{n\,\bar{x}}\right) \qquad ....(3)..$$

Where:
n is the number of the water depth applied, each representing an equal irrigated area
Xi = measured application depth (mm or cm)
μ = mean application depths of (mm or cm)

CU= coefficient of uniformity percentage. The coefficient of uniformity (Cu) can be an expression in the following form:

$$\text{Cu\%} = \{100(1 - \frac{\text{The standard deviation of water in the catch can}}{\text{Mean of the water in the catch can}})\}$$

Distribution Uniformity (DU):

Merriam and Keller (1978) defined their "distribution uniformity, the coefficient" as follows: DU%=100 X [($average\ low\ quarter\ of\ water\ in\ the\ catch\ can$)/(the$average\ total\ of$ ....(4)

DU%= distribution uniformity percentage

The largest depths could also be used to express DU but since the low values in irrigation are more critical, the average of the smallest depth in the lowest quartile is used (Burt et al., 1997). Du is a helpful measure of the severity of distribution issues. A low Du value suggests that deep percolation losses are excessive. Values below 67 percent are often regarded as undesirable (Merriam and Keller, 1978). PELQ, on the other hand, measures how well the system can apply water under ideal management. Low distribution uniformity (DU) and potential application efficiency of the low quarter (PELQ) values suggest design or management problems. These values are presented as fellow:

Du =dw/Dw x 100 .... (5)

Potential efficiency of low quarter (PELQ)

PELQ = dw/Dg x 100 .... (6)

/By (Al-Ghobari, 2006)

Where: DW is the average weighted low quarter depth (mm).

Dw is the average weighted depth applied (mm). Dg is the average depth of water applied (mm).

RESULT & DISCUSSION

The sprinkler system's on-field effectiveness has been evaluated using the coefficient of uniformity, distribution uniformity, and potential application efficiency of the low quarter.

When operating pressure is constant and riser height it was taken into account the evaporation and drift losses descent from (10.2 to 8.57%) when riser height increased from 1.0 to 2.0 m, this up normal result was illustrated due to a decrease in temperature about 9.4 C^o and increase of relative humidity 17% at the morning run in May 2021, whereas the result shown increased in evaporation and drift losses from (8.47 to 13.02%) when riser height increased from 1.0 to 2.0 m at morning in (June –July 2021) due to increase in temperature and decreased in relative as indicated in Table 2**.**

The optimum equation for forecasting the evaporation and drift losses from the sprinkler technique is shown in table 2. (Column7), calculated by power equation using field weather data, and riser height (m) as a variable. To compare the results obtained by the current study with that obtained by Abo-Ghobar (1994), as proposed by Drapper and Smith (1966) (Column 8). It was clear that results obtained by the current study ranged between (8.47-13.02%), in time results obtained by Abo-Ghobar (1994) successive ranged between (7.35-7.98%). The difference may be due to the mean of calculation equations and diverseness in weather conditions.

Table (2): The losses of evaporation and drift (%) at (1&2m) riser height and wind speeds in interval period.

Two Period	Time	Riser height	Wind speed (m/sec)	Air temperature ($C^{o)}$	Relative humidity (%)	Evaporation and drift loss(%)	Drapper & Smith (1966) equation
	Morning	1	0.71	34.43	11.2	10.20	7.3603
May,2021		2	1.07	25.00	28.21	8.57	7.8598
	Evening	1	1.43	34.80	13.76	11.60	7.4482
		2	2.24	28.73	24.03	11.37	7.9705
	Morning	1	0.75	33.67	16.07	8.47	7.3529
J-J,2021		2	1.94	35.73	8.77	13.02	7.9421
	Evening	1	2.15	37.67	17.10	12.62	7.4971
		2	1.93	26.83	9.30	10.03	7.9865

Catch can evaporation

Table.3 a, b & table.4 shown linear correlation equations between water volume in (L) and evaporation loss (mmh-1) from the water in all run tests “catch cans” at two time periods (May & June - July 2021), the correlation coefficients R^2 ranged between (0.91-0.72%), the heights correlated between water volume and evaporation losses was illustrated in morning test in May 2022, R^2=0.91. It was shown that evaporation losses from collected water in “catch cans” decreased proportionally as water volume increased, this result might be due to the high-temperature effect and low relative humidity,
the findings corroborated those of Doorenbos an d Pruitt (1984).

Table (3): a. Evaporation from “catch cans” during the test run (intervals) in May 2021.

Time Test	Riser Height (m)	Operation Pressure (Bar)	Collected volume (L)	Evaporation From can (mm/h)
Morning	1	1	0.081	3.92
	1	2	0.089	1.85
	2	1	0.090	1.28
	2	2	0.102	3.06
Evening	1	1	0.082	3.86
	1	2	0.090	0.98
	2	1	0.084	2.00
	2	2	0.093	0.71

Table (3): b Evaporation from “catch cans” during the test run (intervals)in (June &July 2021).

Time Test	**Riser Height (m)**	**Operation Pressure (Bar)**	**Collected volume (L)**	**Evaporation From can (mm/h)**
	1	1	0.093	3.40
	1	2	0.096	2.21
Morning	2	1	0.097	2.01
	2	2	0.106	1.33
	1	1	0.09	4.33
Evening	1	2	0.099	3.32
	2	1	0.092	5.41
	2	2	0.100	2.20

Table(4): Correlation equation between "catch cans" volume in two run tests (morning and evening) and two time periods.

Time Interval	Run test	Correlation equation	R^2
May 2021	Morning	Y=-177.62X+17.850	0.91
	Evening	Y=-253.81X+24.032	0.83
June-July,2021	Morning	Y=-136.06X+15.572	0.78
	Evening	Y=-232.98X+26.006	0.72

Wind speed:

Tables 5. (a & b) shown that the impact of wind speed on water application uniformity was tested at two different times of the day (morning, & evening), and at two time periods (May and June –July 2021) the research region saw ongoing fluctuations under various wind speeds and directions, the percentages of coefficients (CU and DU) may vary for a variety of causes, including random variations in, pressure changes at sprinklers, the impact of operating pressure and riser height. Low (CU%, DU%), and (PELQ%) can be observed at low pressure and high riser height, which may be caused by the low discharge of applying sprinkler. CU, DU, and PELQ percent were also highly significantly impacted by riser height, in both time periods (May and June –July 2021). Conversely coefficient (PELQ%) was not affected directly by riser height Table 5a. Whereas, riser height increased, the (CU%, DU%) were decreased, this may due to the unpredictability of wind gusts and turbulence contributes to smoothing out the distribution pattern as indicated by Merkley and Allen (2004). Therefore, it is not suggested to run the sprinkler system at wind speeds of 2.6 and 3.6 ms^{-1}. The overall pattern of the findings was consistent with those reported by Yazar (1984).

The performance Parameters Analysis:

The results that were obtained are displayed and discussed in this subsection, to calculate and evaluated evaporation and drift losses: Table5. a & b shown the means of the three coefficients that were calculated depending on the water volume collected from the sitting catch cans under different weather conditions, operation pressures, and height risers.

Coefficient of uniformity (CU%):

The values of Christiansen (1942) created the non-weighted coefficient of uniformity (CU%) that was calculated depending on equation (3). and shown in Table5. a & b the various run time (morning, evening) at two operating pressures (1.0 and 2.0 bar) and two riser heights (1.0 and 2.0 m). Statistically highly significant differences between the mean of run time ($P > 0.01$) using LSD test in (May 2021) period and showed significant differences between the mean of run time ($P < 0.05$) applying LSD test in (June – July 2021) period. The values obtained at operating pressures of 2.0 bar were greater than those obtained at operating pressures of 1.0 bar, according to Kay (1983), this outcome could be caused by the fact that water under low pressure is split up into big droplets that fall close to the sprinkler. However, according to Keller and Bliesner (1990), all values are acceptable and ranged between (40-80%). All of the CU percent results from the evening tests were lower than those from the morning testing. This outcome might be attributed to the morning's greater relative humidity, lower temperature, and slower wind speed compared to the evening.

Distribution uniformity (DU%):

Defined their "distribution uniformity coefficient" U percent is a useful indicator of how serious distribution problems are measured according to Merriam and Keller's (1978) formula number (4), Due to the value denotes high deep percolation losses. Values under 67 percent are frequently thought to be undesirable (Merriam and Keller, 1978). Under two working pressures (1.0 and 2.0 bar) and two riser heights (1.0 and 2.0 m), there were highly significant differences ($P > 0.01$) between the values of DU percent at various run times (morning & evening). Best values of DU % were noted under operating pressures of (2.0 bar) for the various test periods. The greatest DU percent measurement was 67.4 percent at 1.0 m riser height and 2.0 bar operating pressure in the evening run time in (May 2021) period. Whereas, the greatest DU percent recorded was 67.4 percent at 1.0 m riser height and 2.0 bar operating pressure in an evening run time in (June –July 2021) period. The measurement values less than that permissible DU% exceeded the minimum 60 % set by Keller and Bliesner (1990) in both time periods (May & June –July 2021). Decline Du% value less than 60 % perhaps due to environmental conditions or leak in the sprinkler irrigation system. Also, low operating pressure and strong wind speeds were related to lower DU percent results. It was shown that all DU% measurements run test during the evening tests were lower than those made during the morning run test.

Potential application efficiency of the low quarter (PELQ):

This coefficient is calculated by equation (6) (Al-Ghobari, 2006), It is helpful to measure how well the system can apply water under ideal management. The PELQ should be established to assess water supply and what amount of water is needed to completely irrigate the field may then be calculated. The (PELQ%) is always a little lower than DU in sprinkler irrigation systems (Merriam and Keller 1978). Table 5. (a & b) shows under two operating pressures (1.0 - 2.0 bar) and two riser heights (1.0 – 2.0 m), there were non-significant differences between the means values of various run times (morning & evening) when applying (PELQ%) as an indicator, in time highly significant differences ($P<0.01$) shown among the value of (PELQ%) at various raiser height and operation pressure, the means of (PELQ%) ranged between 53% - 70% in (May 2021) period, on the other hand, highly significant differences between the values of (PELQ%) ($P<0.01$)at various run times (morning & evening), riser height, and operation pressure using the LSD statistical test .Table5. b). The (PELQ%) values ranged between (38.5 % - 55.5%) in (June & July 2021) period. The current result was less than that found by (Merriam and Keller 1978) may be due to the rise in temperature degree and low relative humidity in the mid of summer in the study region, despite the fact that year 2021 was considered a drought year with only (1/3) of the average seasonal rainfall occurred.

Table (5):a Effect of operating pressures, riser heights, and wind speeds on the (CU%) ,(DU%), (PELQ%)during test runs in May 2021.

Time	Wind speed (m/sec)	Riser Height (m)	Operation pressure (Bar)	Means (CU%)	(DU%)	(PELQ%)
Morning	0.71	1	1	73.030	61.657	61.023
	0.21	1	2	76.200	65.733	63.427
	1.07	2	1	75.450	61.497	67.277
	2.18	2	2	77.757	64.227	70.157
Evening	1.43	1	1	69.453	61.343	53.077
	1.75	1	2	73.693	67.400	63.267
	2.24	2	1	66.56	52.940	54.430
	3.10	2	2	67.900	54.650	63.860

Table (5):b Effect of operating pressures, riser heights, and wind speeds on the (CU%), (DU%), (PELQ%) during test runs in (June-July, 2021)

Time	Wind speed (m/sec)	Riser Height (m)	Operation pressure (Bar)	(CU%)	(DU%)	(PELQ%)
Morning	0.75	1	1	60.953	49.570	49.657
	1.09	1	2	72.780	60.747	51.790
	1.94	2	1	60.123	41.077	49.703
	1.73	2	2	60.453	47.340	57.907
Evening	2.15	1	1	51.353	36.777	40.570
	3.49	1	2	54.257	31.550	38.503
	1.93	2	1	54.730	45.640	40.827
	2.84	2	2	61.350	60.440	55.487

Not, (CU%) Christiansen's coefficient, uniformity, (DU%) distribution uniformity, (PELQ%) Potential efficiency of the low quarter.

CONCLUSION

At low wind speeds, low temperatures, and high relative humidity, high efficiencies were obtained. The better test run of sprinkler irrigation was in the morning time due to low temperature, low wind speed, and high relative humidity. Riser height affected significantly sprinkler irrigation system performance. It was found that CU, DU, and (PELQ%) percent values increased with a slight increase in wind speed in the current study the result shown in the morning (June –July 2021) evaporation and drift losses increased from (8.47 to 13.03%) when riser height increased from 1.0 to 2.0 m due to increase in temperature and a decrease in RH%. The study concluded that (CU &

DU%) values obtained at operating pressures of 2.0 bar were greater than those obtained at operating pressures of 1.0 bar, this outcome could be caused by the fact that water under low pressure is split up into big droplets that fall close to the sprinkler. It is not suggested to run the sprinkler system at wind speeds of (2.6 and 3.6 ms^{-1}) and finally, the results of this study emphasized the fact that various coefficients of performance (CU, DU%), and (PELQ%) mainly depend on the field conditions, and one is not allowed to use a given coefficient for any other field condition

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