SOME METHODS FOR CALCULATING LOSSES OF FIXED SPRINKLER IRRATION UNDER THE INFLUENCE OF OPERATION PRESSURE AND SPRAYERS' ARRANGEMENT

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ABSTRACT

A field experiment was conducted in Al-Furat village-Heet district-Al-Anbar governorate-Iraq, in fall season-2017 aimed to evaluate some calculating methods of sprinkler irrigation losses calculated according to each of catch, athelen, and electrical conductivity methods. The experiment included two factors, first; operational pressure (P) with three levels; 250(p_1), 300(p_2), and 350(p_3) kPa, while the second factor; sprayer arrangement (A) with two arrangements; rectangular (A_1) with a space (24*18) m and square (A_2) with a space (18*18) m. The results showed that the operational pressure 250 KPa with rectangular arrangement gave the highest percentage of sprinkler irrigation losses; 27.55%, 23.89%, and 8.20% for the catch, athelen, electrical conductivity methods, respectively. While the operational pressure 350 kPa with square arrangement gave the lowest percentage of the losses; 2.64%, 2.85%, and 9.36% for the catch, athelen and electrical conductivity methods, respectively. Therefore, the reduction of sprinkler evaporation losses depending on the used methods has provided quantities of water to be used to irrigate other areas of the unused land, added to the farmland, in order to achieve the food security that is proportional with the increasing population growth.

Keywords: Sprinkler irrigation losses, operational pressure, sprayers' arrangement, fixed sprinkler irrigation, losses calculation

بعض طرائق حساب فواقد الري بالرش الثابت تحت تأثير الضغط التشغيلي وترتيب المرشات

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المستخلص

أجريت تجربة حقلية في ناحية الفرات–قضاء هيت–محافظة الأنبار/العراق في الموسم الخريفي لعام 2017 بهدف تقييم بعض طرائق حساب فواقد الري بالرش المحسوبة وفقا لطرائق علب التجميع والرقائق اللدائنية والإيصالية الكهربائية. أشتملت التجربة عاملان، الأول؛ الضغط التشغيلي (P) وبثلاث مستويات 250(p_1) و 300(p_2) و 350(p_3) كيلوباسكال، أما العامل الثاني؛ ترتيب المرشات(A) وقد كان بترتيبين، هما؛ المستطيل(A_1) بفاصلة(24*18)م والمربع(A_2) بفاصلة(18*18)م. أظهرت نتائج التجربة ان الضغط التشغيلي 250 كيلوباسكال وبالترتيب المستطيل أعطى أعلى النسب لفواقد الري بالرش، إذ بلغت 27.55%و 23.89% و 8.20% والمحسوبة وفقاً لطرائق علب التجميع والإيصالية الكهربائية والرقائق اللدائنية، حسب الترتيب. فيما أعطى الضغط التشغيلي 350 كيلوباسكال وبالترتيب المربع أدنى النسب من الفواقد، إذ بلغت 2.64% و 2.85% و 9.36% والمحسوبة وفقاً لطرائق الرقائق اللدائنية وعلب التجميع و الإيصالية الكهربائية، حسب الترتيب. لذا فأن انخفاض فواقد التبخر بالرش بأعتماد الطرق المتبعة، قد وفرت كميات من المياه لكي يتم الإستفاد منها في إرواء مساحات أخرى من الأرض الغير مستغلة، تضاف إلى الرقعة الزراعية، سعياً لتحقيق الأمن الغذائي الذي يتناسب و النمو السكاني المتزايد.

الكلمات المفتاحية: فواقد الري بالرش، الضغط التشغيلي، ترتيب المرشات، الري بالرش الثابت، حساب الفواقد

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INTRODUCTION

The sprinkler irrigation systems are characterized by many features that make it spread. And the most eminent of these features are its high efficiency if its design, execution and operating are done well compared with the methods of irrigation by immersion, and possibility of using them in the undulating lands being without need to the settlement processes, and it's also characterized by irrigating the gypsiferous lands, the lands whose light sandy textures and the lands that the ground water level may raises in it and that requires a special management for the irrigation processes, plus many features. Then most eminent of the negatives is the losses associated with spraying process, where these losses represent all the water losses occur between water exiting from the sprayers and its dropping on ground or plant. (Hachem and Yaseen) and (Seginer and Kostrinsky) (9,15) had classified these losses to evaporation losses, drift losses and interception losses. The percentage of sprinkler losses varies according to climate conditions, type of sprayer and the method of design. Myers *etal* (13) verified that the evaporation losses by water drops shouldn't exceed 5% from the added water. Seginer and Kostrinsky (15) classified the water losses in sprinkler irrigation networks (considering from water exiting the sprayers) to evaporation losses from water packet exiting the nozzle before dropping on ground, and inside the collection cans and its percentage depends mainly and directly on temperature, relative moisture, and slightly depends on the wind speed, water drops drifting with the wind outside the field borders, and the water drops rebounding from inside the collection cans (Splash losses) that are scattered outside the collection cans that are stuck to its internal walls. Then Tarjuelo *etal* (19) indicated that that the shit and accurate understanding of the environmental and climate factor (Temperature, relative moisture, and wind speed) that actually affect on evaporation losses by irrigation system, are considered a basic factor to maintain and develop these systems to reduce the percentage of losses. The huge part of losses occurs with the plan which the water leaves the nozzle until it reaches the soil (10,17). Many researches have been conducted with the aim of estimating the sprinkler losses, then Al-Rawi (3) found that the evaporation losses estimated by catch method have ranged between 10% and 42% and he showed that there're no correlations for these losses with the climate changes. Al-Mehemdy (2) found that the evaporation losses ranged between 21.3% and 38% when measuring the differences between water depths at the soil surface with the discharges of sprayers' nozzle. Abo-Ghobar (4) mentioned that the losses are directly proportional to the wind speed, pressure of the saturated vapor and inversely proportional to the relative moisture of air and the size of sprayer nozzle, and he got a close relationship between the losses and deficit of the vapor pressure in air. Anonymous (5) arranged the factors that affect in the sprinkler irrigation losses (SSL) as following: nozzle diameter > relative moisture > temperature, while Wiersma (18) indicated that the wind speed, operational pressure, and solar radiation are important factors effecting evaporation and this is reflected in losses percentage, Increasing the operating pressure leads to decrease the size of water drops and increases the total surface area of the drops and therefor leads to increase the evaporation losses by the effect of wind speed (8). Frost and schwalen (7) indicated that the catch method used in measuring the sprinkler losses gives an estimate more than the real losses and he attributed this that the collection cans whatever their type is (metal or plastic), they are heated by the solar radiation and this causes an increase in the percentage of measured losses that may reach 70%. (14) that the error percentage mentioned by (11) may happen when the test takes a long time and assuming that the amount of water falling on ground surface and plant has been fully leaked, but what often happens is that a ratio of spray water remains stuck as drops on the plant surfaces and another is gathered between the grooves of soil surface, and these drops are exposed to the evaporation. Hachem and Yaseen (9) confirmed that the catch method used in evaluating the sprinkler losses is inaccurate and accompanied with many measurement errors. Kincaid and Longely (10) added that diameter of cans that could be used to evaluate the sprinkler irrigation losses can affect on the results, and he showed that the international criteria of evaluating sprinkler irrigation suggested that the cans diameters have to be bigger than 85 mm. Then Yozar (20) indicated that the evaporation losses and water drops drifting from the fixed sprinkler irrigation system and that estimated by method of the electric conductivity have ranged between 1.50% to 16.80% from the size of total spray water, and there's an exponential function between evaporation function and each of wind speed and operational pressure when using them for magnesium oxide method in the estimation, and he found that the sprinkler irrigation losses have arranged between 1.50% and 15.10% and he added that there's an increase in these losses and with the increase of wind speed and a decrease by the increase of distance with wind direction. Mclean *etal* (12) found that the average of sprinkler losses under pivot sprinkler irrigation system when estimating them by electric conductivity method has reached 9.38% from the water amount, while it has reached 13.05% from fixed sprinkler irrigation system. This study aims to:

1. Diagnosing the effect of the operational pressure and sprayers' arrangement as a two basic factors in the percentage of sprinkler losses.
2. Evaluating some of the different estimation methods under conditions of the study region and choosing the best based on their accuracy and simplicity.

MATERIALS AND METHODS

A field experiment was conducted in Al-Furat city-Heet district/Al-Anbar/Iraq in fall season 2017, aimed to knowing the effect of each the operational pressure and sprayers' arrangement on the sprinkler losses then evaluating the methods of estimating these losses. The fixed sprinkler irrigation system was used, table 1 showed the specifications of irrigation system used in the study. The experiment was conducted by two factors; first, operational pressure (P), three operational pressures were used for the sprayers;

p_1= Operating the sprayers with 250 kPa
p_2= Operating the sprayers with 300 kPa
p_3= Operating the sprayers with 350 kPa

And second; factor; sprayers' arrangement (A); two arrangements were used for the sprayers;

A_1= Rectangular arrangement; the sprinklers spacing have the same lateral line (18) m and the space between two opposite sprayers on two adjacent lateral lines is (24) m which the sprayers' spacing are (18*24) m.

A_2= Square arrangement; both spacing are (18) m, which the sprayers' spacing is (18*18) m.

The randomized complete blocks design was used with three replicates, the sprayers' discharges were measured in the field using the volumetric method for three operational pressures. The discharge was measured according to the following equation mentioned in (9):

$$Q = \frac{Vs}{t} \quad [1]$$

Where:

Q= Sprayers' discharge (m^3h^{-1})

Vs= Water volume exiting from the sprayers (m^3)

t= Time (h).

The results of measurement are given in table 2.

Table 1. The specifications of fixed sprinkler irrigation system

Origin	**Turkish**	**Diameter of sprayer rise**	**2.2 cm**
Pump type	**Indian**	**Nozzles diameter**	**3.2*5.16 mm**
Horsepower	**48 HP**	**Length of main tube**	**690 m**
Discharge	**100 m^3hr^{-1}**	**Diameter of main tube**	**6**
Operational pressure	**60 m**	**Diameter of lateral tube**	**3**
Rotation per minute	**200 cycle per $minute^{-1}$**	**Irrigated area**	**1000 m^2**
Height of sprayer's rise	**0.86 m**	**Diameter of water pool**	**(3*10*22.40) m**

Table 2. Rate of sprayer's discharge at the operational pressure

Pressure (KPa)	Water volume (m^3)	Time (h)	Discharge (m^3h^{-1})
p1	0.02	0.00778	2.57
p2	0.02	0.00389	5.14
p3	0.02	0.002778	7.20

Methods of calculating the sprinkler irrigation losses

***Catch method**

The sprinkler irrigation losses (SSL) were calculated according to catch method mentioned by (13), where each treatment square was installed in a square (length of rib 3m) then a cylinder metal can (height 0.2m and diameter 0.01m) was placed inside the center of each square and it was fixed in the soil so its upper edge raises the soil surface about 0.05 m, and the spaces between cans were 3*3 m. The catchments were measured for each irrigate by a volumetric cylinder then converting it to a water depth by dividing the received water volume to the surface area of cans. The equation mentioned in (9) was used to calculate the sprinkler irrigation losses, and as following:

$SSL = \frac{Vs-Vi}{Vs}\times 100$ [2]

Where:

SSL= sprinkler irrigation losses (%).

Vi= water volume reaching the ground (m^3), and it's calculated by the following equation:

Vi= Dc *S *L [3]

Where:

Dc = Rate of water depth received in the cans (m)

S = space between a sprayer and another one on the same line (m)

L= space between two opposite sprayers on two adjacent lateral lines (m).

*** Athelen method**

The sprinkler irrigation losses (SSL) were calculated according to the athelen method mentioned by (13), and that by compiling the spray water falling on impervious surface by making the four sprayers work in a sufficient area covered by plastic flakes and the surface is calibrated with a gradient towards a point or more to compile the water quickly for measuring the water volume compiled within the nylon lath. The measurement was done inside a cylinder (height 0.98m and diameter 0.30m), the measurements were done with an empty area from plants for both arrangement and for all operational pressures, and they were conducted at end of the experiment. And sprinkler irrigation losses were calculated according to the equation (2).

*** Electrical conductivity method:** The sprinkler irrigation losses (SSL) of electrical conductivity method were calculated according to the equation mentioned in (1), as following:

SSL= 72.63x+2.1 [4]

Where:

x= the relative difference in the salinity of water added from the source and consumed on the soil surface, and it's calculated by the following formula mentioned in (1):

$x = \frac{Eca-Ecs}{Eca}$ [5]

Where:

Eca= Electrical conductivity of the water received in the cans (dSm^{-1}).

Ecs= Electrical conductivity of the irrigation water at the source (dSm^{-1}).

RESULTS AND DISCUSSIONS

Sprinkler irrigation losses by catch method

Table 3 shows the sprinkler irrigation losses calculated by catch method, where it's noticed that increasing the operational pressure led to decrease the SSL and for both arrangement. In the rectangular arrangement, the SSL decreased from 27.55% to 14.58% and 5.86% by increasing the operational pressure from 250 to 300 and 350 kPa, respectively. As for the square arrangement, SSL have decreased to 7.64% at the operational pressure 250 kPa, to 1.66% at 300 kPa and then it slightly increased to 2.85% at 350 kPa, respectively. Increasing the operational pressure leads to decreasing the volume of water drop and increasing the total surface area of it and therefore increasing the sprinkler irrigation losses. But the increase of pressure led to increase the discharge of sprayer with stability of given water volume and this will lead to abbreviating the irrigation time that affects the evaporation time and therefore reducing the losses percentages, this is consistent with what mentioned by Green *etal* (8). Table 3 shows that SSL calculated by catch method have decreased in the square arrangement comparing with the rectangular arrangement, where SSL decreased at the operational pressure 250 kPa from 27.55% in rectangular arrangement to 7.64% in square arrangement, and at the operational pressure 300 kPa, the losses decreased from 14.58% in rectangular arrangement to 1.66% in square arrangement, then at the operational pressure 350 kPa, the (SSL) decreased from 5.86% in rectangular arrangement to 2.85% in square arrangement.

That's attributed to that the square arrangement decreased the wind effect by the closeness of distances between sprayers, and this agrees with what mentioned by Hachem and Yaseen (9).

Sprinkler irrigation losses by athelen method

Table 4 shows SSL calculated by athelen method, where it's noticed that increasing the operational pressure led to decreasing the SSL for both arrangement. In the rectangular arrangement, the losses decreased from 8.20% to 5.66% and 1.54% by the operational pressures 250,300 and 350 kPa, respectively. As for square arrangement, the values have the same trend, where the SSL decreased from 5.79% to 5.59% and 2.64% at the operational pressures 250,300 and 350 kPa, respectively. The decrease of SSL at athelen method is due to there's no water losing outside the borders of measurement region, that is most of water emanating from the four sprayers gather in the nylon lath allocated for measuring compared with the Catch method, and this agrees with what mentioned by Kincaid (10) that the diameter of cans used in evaluating the SSL has a positive effect on the obtained evaluation. Table 4 also shows that SSL calculated by athelen method have decreased in square arrangement comparing with rectangular arrangement, where they decreased from 8.20% to 5.79% at the operational pressure 250 kPa, from 5.66% to 5.59% at 300 kPa, then they raised from 1.54% to 2.64% at 350 kPa, and this reduction of SSL within square arrangement comparing with rectangular arrangement when depending the athelen method may be attributed to that the diameter of wetness circle was improved in which it covered the measurement area that contains the nylon lath which inverted positively to make the compiled water quantity to be more so, the SSL was decreased, on the other hand, this agrees with Myers *etal* (13) who indicated that the evaporation losses of water drops shouldn't be more than 5% from the added water.

Table 3. Values of sprinkler irrigation losses calculated by catch method

Arrangement	Pressure (KPa)	Discharge (m^3h^{-1})	Time (Min)	Water volume exiting the sprinklers (m^3)	Water volume reaching the ground (m^3)	(SSL) within collecting cans (%)
Rectangular	250	2.57	151	6.46	4.68	27.55
	300	5.00	070	5.83	4.98	14.58
	350	7.20	054	6.48	6.10	5.86
Square	250	2.57	113	4.84	4.47	7.64
	300	5.00	058	4.83	4.75	1.66
	350	7.20	041	4.92	4.78	2.85

Table 4. Values of sprinkler irrigation losses calculated by athelen method

Arrangement	Pressure (KPa)	Discharge (m^3h^{-1})	Time (Min)	Water volume exiting the sprinklers (m^3)	Water volume reaching the ground (m^3)	(SSL) by athelen method (%)
Rectangular	250	2.57	151	6.46	5.93	8.20
	300	5.00	070	5.83	5.50	5.66
	350	7.20	054	6.48	6.38	1.54
Square	250	2.57	113	4.84	4.56	5.79
	300	5.00	058	4.83	4.56	5.59
	350	7.20	041	4.92	4.79	2.64

Sprinkler irrigation losses by electrical conductivity method

Table 5 shows SSL calculated by the electrical conductivity, where it is noticed that the SSL have decreased with increasing the operational pressure for both arrangement. The SSL of rectangular decreased from 23.89% to 20.26% and 16.63% at the operational pressures 250,300 and 350 kPa, respectively. As for square arrangement, the SSL have decreased from 15.17% at the operational pressure 250 kPa to 9.36% for the operational pressures 300 and 350 kPa, respectively, and this is attributed to that the evaporation losses are related to the operating time and environmental conditions, that is the irrigation by depending low operational pressure takes a long time than the high operational pressure, which increasing the wind effect and temperatures and therefore increasing the percentage of evaporated water, and this agrees with (15,16). Table 5 shows that the SSL have decreased in the square arrangement comparing with rectangular arrangement and by depending all the operational pressures, where they have decreased from 23.89% to 15.17%, from 20.26% to 9.36% and from 16.63% to 9.36% according to the operational pressures 250,300 and 350 kPa, respectively. This is attributed for two matters, first; irrigation time, where it was longer in rectangular arrangement and therefore the sprayers are exposed to the wind effect and temperature, which increased the chance of evaporation of these drops in the air comparing with the square arrangement, and this agrees with what mentioned by (19). And second; it may be attributed to increasing salt concentration due to evaporation losses.

Comparison between the studied methods

Table 6 shows the reduction of sprinkler irrigation losses by the athelen method with the other methods and according to the depended operational pressures, where at the operational pressure 250 kPa, Sprinkler irrigation have reduced to 8.20% comparing with 27.55% at catch method, 23.89% by electric conductivity, then the other pressures and methods have taken the same trend in reducing, where at the operational pressures 300,350 kPa, sprinkler irrigation losses have reduced by the athelen method to 5.66% and 1.54% comparing with 14.58% and 5.86% by catch method, 20.26% and 16.63% by electric conductivity method when applying rectangular arrangement, respectively. The reason of reduction of sprinkler irrigation losses by athelen method comparing with the other methods depended in experiment may be attributed to the uniformity and interaction occurred between the elements of this method that is represented by water size exiting the sprayers, water volume at the cans, and the electric conductivity of water, plus the operational pressure that is by increasing it, sprinkler irrigation losses have decreased due to the reduction of spray time. Table 7 shows that the reduction of sprinkler irrigation losses by the athelen method is bigger than the other methods depended in this study especially in the square arrangement comparing with rectangular arrangement, where at 250 kPa operational pressure, the values the values of losses have decreased from 8.20% to 5.79% comparing with catch method where they have decreased from 27.55% to 7.64%, from 23.89% to 15.17% by electric conductivity, then the other operational pressures have taken the same trend in reducing at the same depended methods. It's thought that the reason of reduction of sprinkler irrigation losses by athelen method is due to the uniformity between elements of this equation, as well as the integrative role of square arrangement that minimized the distances, which made amounts of water to be falling much more in the cans allocated for collecting the water and increasing the wetness diameter, which decreased the effect of wind speed and therefore the drops don't drift outside the lath of collection.

Table 5. Values of Sprinkler irrigation water calculated by electrical conductivity method

Arrangement	Pressure (KPa)	Discharge (m^3h^{-1})	Time (min)	(Ec) of water received in cans (dSm^{-1})	(Ec) of irrigation water at source (dSm^{-1})	Relative difference of irrigation water salinity	(SSL) by electrical conductivity (%)
Rectangular	250	2.57	151	1.28	1.28	0.90	23.89
	300	5.00	070	1.20	1.20	0.90	20.26
	350	7.20	054	1.12	1.12	0.90	16.63
Square	250	2.57	113	1.10	1.10	0.90	15.17
	300	5.00	058	1.00	1.00	0.90	9.36
	350	7.20	041	1.00	1.00	0.90	9.36

Table 6. Values of sprinkler irrigation losses by athelen method comparing with the other methods

Arrangement	Pressure (KPa)	Discharge (m^3h^{-1})	Time (min)	Sprinkler irrigation losses by the following methods (%)		
				Catch method	Electric conductivity method	Athelen method
Rectangular	250	2.57	151	27.55	23.89	8.20
	300	5.00	070	14.58	20.26	5.66
	350	7.20	054	5.86	16.63	1.54
Square	250	2.57	113	7.64	15.17	5.79
	300	5.00	058	1.66	9.36	5.59
	350	7.20	041	2.85	9.36	2.64

Conclusion and Recommendations

It was showed that depending the athelen method with the square arrangement has given a minimum percentage of the evaporation losses under fixed sprinkler irrigation system and at 350 kPa operational pressure, where the reduction percentage reached about 54.95% when comparing between catch method by rectangular arrangement and athelen method by square arrangement, so we recommend to use the athelen method in estimating the spray losses when depending fixed sprinkler irrigation system in province of middle and west of Iraq, which is classified as an arid and semi-arid areas

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