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Evaluating the Performance of Locally Used and Produced Drip Irrigation Systems

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Abstract:

Drip irrigation is a system for supplying filtered water and sometimes fertilizer directly onto or into the soil. Clogging causes poor distribution along the lateral line, and it may take time before they are discovered, cleaned, or repaired, resulting in a poor distribution of plant watering along the lateral line. As a result, it is necessary to investigate the hydraulic performance of these systems to zero in on the most important influencing parameters. In this study, the irrigation systems produced and imported, which are frequently used by farmers in the Iraqi Governorate of Kerbala. The results obtained for systems of drip irrigation indicate when using dripper (1), the field uniformity ranged between 73.4% to 88%. The uniformity of absolute ranges between 73% and 86% and the design uniformity range between 70.8% and 85.2%. The uniformity coefficient of statistical (SU_c) was ranging between 73.4% and 88.6%. The coefficient of variation (c_v) for the irrigation system was ranging between 0.26 and 0.11%. The efficiency of application ranged from 73.4% to 86.8%. When using dripper (2), the field uniformity obtained ranged from 84% to 95%, the uniformity of absolute ranged between 83% and 94%. The design uniformity ranged from 79.7% to 93%, and the uniformity coefficient of statistical (SU_c) was ranging between 86% and 95%. The coefficient of variation (c_v) ranged from 0.13 to 0.05%, and the efficiency of application ranged between 82.5% and 94%.

Keywords: Coefficient of variation; Drip irrigation system; Emitter flow; Performance evaluation; Pressure variation.

1. Introduction:

Drip irrigation is the slow and controlled application of water to plant root areas through spaced emitters and at specified intervals [1]. Water is supplied directly to plant roots with low pressure and flow rate to meet the crop water requirement [2]. The drip irrigation technique is thought to be beneficial because of its high potential application quality, the addition of chemical fertilizers with irrigation water, cultural operations during irrigation, and energy savings. There is a great demand by farmers for the drip irrigation system in desert areas in Iraq, due to the great benefits of this system, as well as the scarcity of water that is often the water of wells and the nature of sandy lands in that region. In recent years, the problem of water shortage has increased due to climate change as well as some imposed unacceptable water policies such as the construction of dams on the rivers in the neighbouring countries which led to a scarcity of river discharges. It was necessary to evaluate and test the performance of the drip irrigation systems used and produced in the governorate and to find out their suitability to the standard specifications and compares each other. The experiment included three types of drip irrigation pipes, two of which were manufactured locally and the third was imported. These three types are the most commonly used in the governorate; additionally, two types of drippers were frequently used by farmers and compared, as shown in Figures 1 and 2.

Figure 1 Emitter No. 1.

Figure 2 Emitter No. 2.

2. Materials and Methods

2.1 District of Fieldwork

The study was conducted on the irrigation networks used in the farms of Karbala Governorate. An irrigation system has been established in one of the governorate's farms located at 44^o 07 '13.8" east and latitude 32^o 31'. 01.8 " N.

This system includes several irrigation networks made from various sources, including those made locally, by the governorate, and the imported type, which is widely used in the governorate's farms situated between the governorates of Karbala and Najaf. Most of the farms in those desert areas are dedicated to the cultivation of tomatoes, cucumbers, and onions and are irrigated by wells using a drip irrigation system. Due to a lack of rainfall, the climatic conditions in that desert region are harsh, with summers being dry and hot and winters being cold.

2.2 Measurements of System Parameters

The drips irrigation system was hydraulically evaluated according to a method suggested by Merriam and Keller [3]. Physical measurements of application rates using catch cans are the best way to test the efficiency of drip irrigation systems. Using measuring cylinders and a stopwatch, two lateral irrigation lines were chosen from used and locally produced ones with a diameter of 16mm for three different irrigation facilities. The test and evaluation process used two types of emitters that are most commonly used by the farmers. The emitters were tested for lateral lines, and the discharge and pressure were measured for eight emitters for each lateral line and using two emitters different. The pressure in the lateral lines was measured with a pressure gauge system, and the discharge of each dripper was measured before calculating all evaluation coefficients. The efficiency of the imported product was compared to the efficiency of the local products, and the efficiency of the first dripper was compared to the efficiency of the dripper number two.

3. Measurements of system performance parameters

3.1 Emissions Uniformity in the Field (EU_F)

For uniformity of water application, Keller and Karmeli proposed two parameters emission uniformity (EU_a) and field emission uniformity (EU_f) [4].

The field emission uniformity can be calculated based on the following equation:

$$\%EU_F = \frac{q_{0.25}}{q_{ave}} * 100 \quad (1)$$

Where, $q_{0.25}$= average of lowest 1/4 of the emitter flow rate (l/h), q_{ave}= average discharge of emitter (l/h). Table 1 shows a classification of emission uniformity.

Table 1 Classifications according to emission uniformity values [3].

EU	Clarification
Over 90%	Excellent
80-90	Good
70-80	Fair
Less than 70%	Poor

3.2 Uniformity of Absolute Emission (EU_a)

The following equation was used to determine the uniformity of absolute emissions:

$$\%EUa = 100 \left[\frac{q_{\frac{1}{4}}}{q_{ave}} + \frac{q_{ave}}{q_X}\right] * \frac{1}{2} \quad (2)$$

Where , q_X = Average of the highest 1/8th of the emitters flow rate (l/h) all other parameters were previously defined[5]. The classification of emission uniformity can be adopted from Table 1.

3.3 Uniformity of Design Emission (EU_d)

The uniformity of design emission was calculated using the following equation.

$$\%EU_d = 100 * \left[1 - \frac{1.27C_V}{\sqrt{N}}\right] * \frac{q_{min}}{q_{ave}} \quad (3)$$

Where, C_V= variation coefficient, N=number of emitters for each plant,

q_{min}= minimum discharge of emitter (l/h) [6]. The classification of emission uniformity can be scaled from Table 1.

3.4 Coefficient of Variation (C_v) and Statistical Uniformity

The coefficient of variation is used for comparing the differences in two or more data sets [7]. It can be written as:

$$C_v = \frac{S_q}{q_{ave}} \quad (4)$$

Where**,** $S_q =$ is the standard deviation of flow[8].The classification of C_v is obvious in Table 2.

$$\%SUc = 100(1 - Cv) \quad (5)$$

Where SU_c =statistical uniformity coefficient. For evaluation SU_c index, one can use Table 3.

Table 2 Classification of coefficient of variation[9].

Coefficient of Variation(C_v)	**Clarification**
Less than 0.1	Excellent
0.2-0.1	Very good
0.3-0.2	Acceptable
0.4-0.3	Low
Over 0.4	Unacceptable

Table 3 Classifications according to statistical uniformity values [10].

Statistical Uniformity (SUc)	**Clarification**
Over 90%	Excellent
80-90	Very Good
70-80	Fair
70- 60	Poor
Less than 60%	Unacceptable

3.5 Variation of Emitter Flow Rate (q_{var})

Emitter flow rate variation was calculated using equation 6.

$$\%q_{var} = 100 * \left[1 - \frac{q_{min}}{q_{max}}\right] \quad (6)$$

Where, q_{max} is the maximum discharge of emitter, l/h., q_{min}= minimum discharge of emitter (l/h). The classification of variation of emitter flow rate can be adopted also from Table 4.

Table 4 Classifications according to variation of emitter flow rate values [11].

Variation of Emitter Flow Rate(q_{var})	Clarification
Above 25%	Not Acceptable
(10 – 20) %	Acceptable
Less than (10) %	Desirable

3.6 Pressure Head Variation (h_{var})

Pressure head variation (h_{var}) is defined based on equation 7.

$$\%h_{var} = \frac{h_{max} - h_{min}}{h_{max}} * 100 \quad (7)$$

Where: h_{max} and $h_{min}$are the maximum and minimum pressure heads respectively, along the lateral lines. In drip irrigation design, the maximum pressure variation allowed is 20% as stated by Michael [12].

3.7 Efficiency of Application (E_a)

Application efficiency is the ratio of water needed in the root region to the total amount of water used, and it can be expressed as follow:

$$\% E_a = \frac{q_{min}}{q_{ave}} * 100 \quad (9)$$

Where, q_{min}= minimum discharge of emitter (l/h),q_{ave}= average discharge of emitter (l/h) [13].

4. HEAD – Discharge Relationship

The following equation expresses the relationship between head discharge and emitters.

$$q = K_d * H^x \quad (10)$$

q = Flow rate in L/h, K_d = Discharge coefficient, H = at the emitter, working pressure head, x= emitter discharge's exponent. Figures 4 and 5, show the relationship between pressure and discharge.

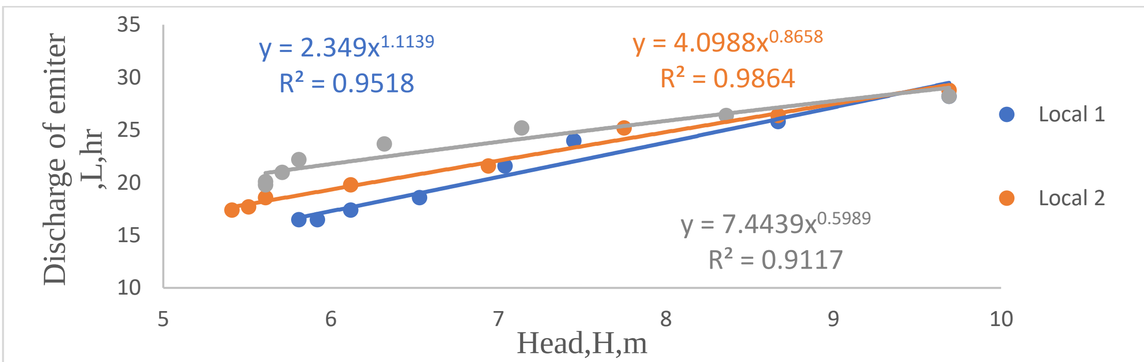

Figure 4 The pressure-discharge relationship for products at pressure 1bar and emitter 1.

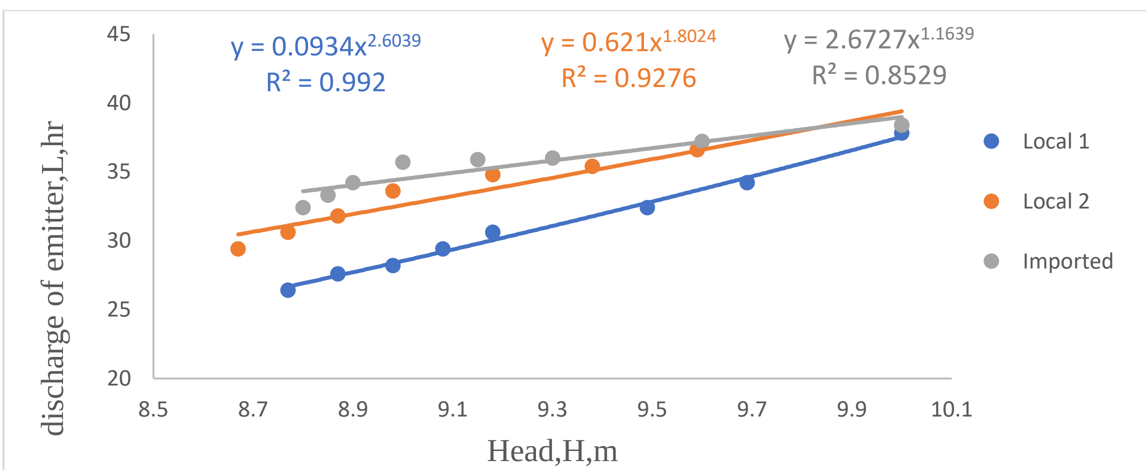

Figure 5 The pressure-discharge relationship for products at pressure 1 bar and emitter 2.

5. Results and Discussion:

Tests on soil samples revealed that the soil is sandy making it ideal for growing crops such as tomatoes, chilli peppers, and cucumbers. There are different criteria for evaluating performance irrigation of drip systems that are absolute emission uniformity (E_a), application efficiency (E_a), field emission uniformity (EU_f), design emission uniformity (EU_d), coefficient of statistical uniformity (SU_C), coefficient of flow variation (C_v), pressure head variation (h_{var}) and emitter flow rate variation (q_{var}). Table 1 shows the results of the calculations for each lateral line. It was noted that from Table 1 that the absolute emission uniformity (EU_a) for 9 latera lines for three different resources and two types of drippers most used locally between 73% - 86% when using dripper 1 and from 83% to 94% when using dripper number 2.

The (EU_f) of the drip irrigation system for nine lateral lines for three different resources and two types of drippers most commonly used in the area. When using dripper number one, the results ranged from 73.4 to 88 %, and when using dripper number two, the results ranged from 84 to 95%. The (EU_d) of the drip irrigation system for the nine lateral lines for three different resources and two types of drippers most commonly used in the area. When dripper 1 was used, their values ranged from 70.8 to 85.2%, and when dripper 2 was used, their values ranged from 80 to 93%.

The (C_v) and the SU_c were calculated for the drip irrigation system for 9 lateral lines. the (SU_c) was closely related to the uniformity of the system. It is used to show the uniformity of the system. The value of the (SU_c) for the irrigation system was ranging between 73.4 % and 88.6 %. The value of the (C_v) for the irrigation system ranged between 0.26 and 0.11. The (E_a) for 9 lateral lines ranged from 73.4 to 86.8% when dripper 1 was used, and from 82.5 to 94% when dripper 2 were used. The values of drip irrigation system head losses due to friction for the 9 lateral lines for three different resources and two types of drippers which was most commonly used locally are reported below. Their values ranged between 0.46 and 1.34 when the lateral length was 25 meters, the number of drippers was 25, and the pipe roughness coefficient C was 140.

Table 5 Parameters of performance and type of emitter 1.

Type. Lateral	No. of lateral	Pressure (bar)	E_a, %	EU_F, %	EU_a, %	EU_d, %	SU_c %	q_{var} %	h_{var} %	c_v
Local 1	1	0.6	73.5	74.8	73	70.8	73.4	48.6	43.3	0.26
		0.8	76.5	79.7	78.5	74.6	82.2	42.8	43	0.17
		1	79	80.5	78	76.9	80.5	42.5	40	0.19
	2	0.6	73.8	75	74	71.4	76.4	48.7	43.3	0.23
		0.8	76	80	78.8	73.9	81.6	44	43	0.18
		1	79	81.8	80	77	83.2	40.4	40	0.16
Local 2	1	0.6	73.4	73.4	75	71	77.9	50	41.7	0.22
		0.8	76.5	79.7	79	74.6	81.7	42	45	0.18
		1	81	82.6	80	79	82.4	39.5	44	0.17
	2	0.6	74.7	74.7	74	72	77.2	50	41.7	0.22
		0.8	77	80.2	78.5	75	81.8	44	43.6	0.18
		1	80	82.7	80	78	83.4	39.5	42	0.16
Imported	1	0.6	79	81.3	80.5	77	83.3	39.4	45	0.16
		0.8	83.8	85.4	82.4	82	84.3	34.8	43	0.15
		1	86	87.9	86	84.8	88.6	29.8	41	0.11
	2	0.6	79	80.6	79.7	77	82.7	39.4	45	0.17
		0.8	82.2	83.7	81.4	80.4	83.7	36.3	43	0.16
		1	86.8	88	84	85.2	87.2	32.6	42	0.12

Table 5 showed that the value of each variation of emitter flow and pressure head variation was high and this indicates that the dripper used was poor.

Table 6: Parameters of performance and type of emitter 2.

Type. Lateral	Pressure (bar)	E_a, %	EU_F, %	EU_a, %	EU_d, %	SU_c %	q_{var} %	h_{var} %	c_v
Local (1)	0.5	82.5	84	83.8	79.7	86	31	25	0.13
	1	85.5	87.6	84.5	82.7	87	30	12	0.12
	1.5	89	91	88.5	87	91	23	11.5	0.08
Local (2)	0.5	83	84	83	80	85.5	32	24	0.14
	1	87	88	88	85	91	23	13	0.09
	1.5	90	92	89	88	92	20	11.5	0.07
imported	0.5	88	89	88	86	90	23	18.3	0.09
	1	91	92	92	90	94	15.6	12	0.05
	1.5	94	95	94	93	95	12.5	10	0.05

6. Conclusions

The decrease in water resources and the increase in desertification areas in Iraq due to climate change and the construction of dams on rivers in neighbouring countries that are riparian with it have resulted in a significant need for proper water management. This means to conserve water and reduce its consumption. It was necessary to conduct a study of the drip irrigation systems used in the governorate's farms producing local and imported products in order to correctly assess their efficiency and the extent of their work and to compare the product produced locally with the imported product

Through the results, it was found that the value of absolute emission uniformity (EU_a), field emission uniformity (EU_F), design emission uniformity (EU_d), and emission efficiency (E_a) was low for local products and were classified as acceptable. When using dripper (1) at operating pressures of 0.6, 0.8, and 1 bar and lateral length of 25 m at drippers every 30 cm, the value increases as the operating pressure increases for imported products and is classified as good.

The results were better when a dripper (2) with lateral lines of length 25 m and a dripper every 1 meter was used instead of a dripper 1. Absolute emission uniformity (EU_a), field emission uniformity (EU_F), design emission uniformity (EU_d), and emission efficiency (Ea) were found to be low for local products and classified as good. When the operating pressure is increased, the values rise. According to Merriam and Keller [3].

The value of the coefficient of variation was higher in local products at the operating pressure of 0.6 bar and was classified as acceptable. But when the operating pressure increases to 1 bar the value decreased and was classified as very good. For the imported product, the coefficient of variation was low and was classified as very good.

When using dripper (2), the results were better from dripper 1 and were classified as very good at operating pressure of 0.5 bar using local products. When the operating pressure increased to 1.5 bar the value decreased and was classified as excellent. The imported product was better than the local products, as the cv values were low at all pressures used and classified as excellent according to mentioned by Solomon [9].

The value of (SU_c) was low and classified Fair at operating pressure of 0.6 bar when using local products. When the operating pressure increases to 1 bar the value increases and is classified as very good. For the imported product, the (SU_c) was high and classified as very good at various pressures (ranging from 0.6 to 1 bar). When using dripper number 2 at pressure 0.5 bar, the value of the (SU_c) is also high and classified as very good. When the operating pressure increases the value of the (SU_c) increases and is classified as excellent according to EL-NEMR, 2012 [10] and Mistry [14].

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تقييم أداء أنظمة الرى بالتنقيط المنتجة والمستخدمة محلياً

الخلاصة: *الري بالتنقيط هو نظام لتوفير المياه المصفاة واحيانا الاسمدة مباشرة على التربة او داخلها ,يسبب الانسداد سوء التوزيع على طول الخطوط الجانبية للري وقد يستغرق الامر بعض الوقت قبل اكتشافها وتنظيفها واصلاحها مما يؤدي الى سوء توزيع سقي النبات لذا من الضروري التحقق والتقييم في الاداء الهيدروليكي لهذه الانظمة للتركيز على اهم المعلمات المؤثرة .في هذه الدراسة تم تقييم انظمة الري المنتجة والمستوردة التي يكثر استخدمها من قبل المزارعين في محافظة كربلاء العراقية. تشير النتائج التي تم الحصول عليها عند استخدام احد المنقطات الى ان تناسق الانبعاثات الحقلي يتراوح بين 73.4% و 88% وتناسق الانبعاثات المطلق 73% و86% وتناسق الانبعاثات التصميمي بين 70.8% و 85.2% وكان معامل التجانس الاحصائي يتراوح بين73.4% و88.6% وكان معامل التباين لنظام الري يتراوح بين 0.26 و0.11 وتراوحت كفاءة الارواء بين 73.4% و86.8%. وعند استخدام منقط اخر على نفس الشبكة كانت النتائج هي تناسق الانبعاثات الحقلي يتراوح بين 84% و 95% وتناسق الانبعاثات المطلق بين 83% و 94% وتناسق الانبعاثات التصميمي*

بين 79.7% و 93%   وكان معامل التجانس الاحصائي يتراوح بين 86% و95% وكان معامل التباين لنظام الري يتراوح بين 0.13 و 0.5 وتراوحت كفاءة الارواء بين 82.5% و 94%.