Evaluation the existing drip irrigation network of Fadak Farm

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Abstract

Drip irrigation is used where water resources are scarce and expensive or have salt problems. This system distributes water over a pipe network to the field and converts it by emitters from the pipe network to the plant. Many experiments were carried out in Fadak Farm that based in the Governorate of holy Karbala / Iraq. This study aims to assess the performance of the drip irrigation systems installed for the date palm. The head discharge relationships for emitters were expressed at different operating pressure, and the best model equipped with the highest R^2 was calculated. Results from established models for the relationship of pressure discharge indicated that the pressure exponent was less than 0.5, which indicated that the type of dripper is compensated pressure. By measuring the discharge rates for emitters, the uniformity parameters, namely: absolute emission uniformity, field emission uniformity, coefficient of variation, application efficiency, design emission uniformity, statistical uniformity coefficient, emitter flow variation and pressure variation were determined. The obtained results for drip system indicate 96.5% for field emission uniformity, 96.25% for absolute emission uniformity, 95.9% for design emission uniformity, 97% for statistical uniformity coefficient, 6.85% for emitter flow variation, 0.026 for coefficient of variation, 96.5% for application efficiency, and 16.98% for pressure variation. In this study, the drip irrigation system was worked well efficiently over the entire study region. The performance of the drip system under study can be classified as excellent in accordance to the criteria used to assess the current drip irrigation system over the defined area of study and compared with the standards laid down.

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

Introduction

Irrigation is the synthetic application of water with the required quantity and time to soil or plant. Irrigation is an instrument for managing the risks to production of agricultural. The possibility of lower yields due to drought is reduced to the lowest level by irrigation, as humidity can be applied to the soil to meet the water requirements of crops. The technique of irrigation can be conducted with drip, spray, surface systems, watering canisters and other applications [1]. Due to the scarcity of water supply and the environmental impacts of traditional irrigation systems, the drip irrigation system receives more interest and plays an important role in agricultural production, especially with high-value cash crops as greenhouse plants, ornamentals and fruit [2]. Drip irrigation can provide high efficiency in application, and achieves higher uniformity for application. Both efficiency and uniformity are important for consistently high yield and for the preservation of water quality when water and chemicals are applied through the irrigation system [3].

Drip irrigation prevents the soil erosion; it can use to provide water and fertilizer. There are two main factors that lead to high efficiency of drip irrigation. The first is that the water soaks in the soil before evaporation or running. Second, is adding water near plants, so that only part of the soil, in which the roots are grown, is wet, and unlike surface irrigation or sprinkler irrigation at all[4]. The causes of clogging emissions are divided into three specific groups: physical, chemical, and biological or organic, such as algae, sediments, bacteria, and crusts.

Water uniformity is affected by several factors, like physical, biological, and chemical, water pressure, temperature, and changes in construction [2]. Drip irrigation requires less water and less labor than other forms of irrigation. For most soils this method is suitable if it use in the right way. Water must be applied gradually to clay soils to prevent runoff and accumulation of surface water. Comparatively, higher emission levels are needed on sandy soils to ensure adequate lateral watering of the soil [5]. Variation in the uniformity of operation of the drip irrigation method may be attributed to many factors. One of these factors is the variation in the manufacturing of emitters or variation in the manufacture of emitters due to tolerances of components, assemblies etc.

Another cause of pressure variation within a device is the friction of the pipes or changes in elevation [6]. An increase in the operating pressure results in an increase in the speed of the water inside the tube by reducing friction with the stability of the cross section area and resulting in an increase in the discharge [7]. The advantages of the drip irrigation method are high application efficiency, chemical fertilizers can be applied during the drip irrigation system, saving energy consumption (as compared to sprinkler irrigation), performing cultural operations during irrigation. The facilitating of irrigation automation, avoiding wetting of the entire surface of the soil in row crops and orchards (which results in reduce water loss through evaporation and lower levels of weed growth), keeping the root zone disease reductions is another advantage [8].

For several purposes, it is important to evaluate the drip irrigation system in order to determine whether the required uniformity of emission discharge is met to determine if the system can be effectively run, to determine the right operation of the device and its components in order to take remedial action as appropriate [9].This experiment was carried out with the aim of assessing the performance of the drip irrigation systems for irrigating date palms in the Fadak Farm in Karbala, Iraq after several years of its use. Because of the aforementioned advantages of drip irrigation, it has been introduced in Iraq as one of the modern types of irrigation, especially in desert farms. Given the expansion of the agricultural area using drip irrigation in the Karbala governorate, where the area of land irrigated by drip irrigation method reached 991 dunums within the irrigation boundaries and 92,598 dunums outside the irrigation boundaries, noting that the total area inside the irrigation area is 292 thousand dunums [10] .Therefore, detailed studies on its efficiency were required, and perhaps this study is one of the first studies in this field..

Materials and Methods

1. Experimental sites

The study was carried out at Fadak Farm in Karbala, Iraq which locate at longitude (43° 52' 44" E) and latitude (32° 43' 23" N), as shown in Fig. 1, on the road linking Karbala governorate and Ain Al-Tamr district west of the holy city of Karbala. The total area of the farm is 2000 dounums, the largest part of which is allocated to palm trees, citrus and other fruits. In general, the climate in the center region of Iraq is a desertic climate with hot, dry weather in summers and cold wet in winters, the spring and fall seasons are relatively short and identified with moderate temperatures [11]. The maximum amount of total rainfall takes place in January and March, and it is about 17 mm. The average total annual rainfall in the area was about 97.2 mm, while the mean annual maximum and minimum temperature are 31.1°C and 17.63°C, respectively, and the mean relative humidity is 46.9%.

Figure 1: Geographical location of the study area according to Iraq (Google map).

2. Layout of the irrigation system

The cultivated area that equipped with drip irrigation system is 376.6 dounums, divided into 15 parts as shown in Fig. 2. The farm is equipped with water from a pool located at the southwestern part of the farm. The pool capacity is about 20 thousand cubic meters and dimensions (73 * 70) meters with a depth of 3.75 meters. The pool receives water from Rushdiya canal, a branch of Hussainiya River originating from the Euphrates. The irrigation system consists of main station with 5 pumps, two of them are electric, each with a power of 90 kW and three diesel 76 kW, twelve sand filters and one fertilizer are used, as can be seen in Fig. 3. The main station supplies the water into main lines with a diameter of 160 mm, sub main lines with a diameter of 90 mm, lateral lines with a diameter of 32 mm and drip lines with a diameter 16mm. Drip line contains four drippers self-compensating type surrounding the palm tree.

Figure 2: Farm scheme.

Figure 3: Filters and fertilizers.

3. Soil investigation

Soil analysis (sieve analysis and hydrometer) can provide important information on the physical and chemical properties that influence soil quality and the suitability for plants and type of irrigation. This is the available traditional method, which is acceptable accuracy and has been used by many researchers, including [12], [5] and [13] .Three samples were taken from different places of the farm using core sampler. The type of soil in the study area according to the results of the sieve analysis and hydrometer is sandy soil that is suitable for the Date Palm and the drip irrigation method

4. Measurements of system performance parameters

Hydraulic evaluation of the drip irrigation system was carried out according to a method suggested by Merriam and Keller [14]. The simplest approach to evaluate the performance of drip irrigation systems involves undertaking physical measurements of application rates using catch can, measuring cylinders and stop watch, as shown in Fig. 4. Four lateral lines were chosen in four different locations of the farm. Each line contains sixteen dripper's rings with four drippers surrounding the plant; eight dripper's rings were selected. The pressure in the laterals was measured using a pressure gauge. The system was evaluated as following;

4.1 Emissions uniformity in field (EUF) and uniformity of absolute emission

Keller and Karmeli [15] proposed two parameters to describe the uniformity of water application by means of a drip irrigation system, namely Emissions uniformity in field (EU_F) and uniformity of absolute emission (EU_a), their relationships are given as

$$EU_F = \frac{q_{1/4}}{q_{ave}} * 100 \quad (1)$$

Where, EU_F = Field emission uniformity%, $q_{1/4}$= the lowest average value of 1/4th of the flow rate of emitter (l/h), q_{ave} =Flow rate average for all emitters (l / h).

General EU values requirements for systems in service for one or more seasons are: more than 90%, excellent; between 80% and 90%, good; 70% to 80%, fair; and less than 70%, poor [14].

Absolute emission uniformity (EU_a)

The uniformity of absolute emissions was calculated using the following equation

$$EU_a = 100 * \left[\frac{q_{min}}{q_{ave}} + \frac{q_{ave}}{q_{max}}\right] * \frac{1}{2} \quad (2)$$

Where, EU_a = Absolute emission uniformity%, q_{ave} =average flow rate through emitter (l/h), q_{min}= minimum flow rate of emitter, l/h, q_{max}= Average flow rate of the maximum 1/8th of the emitters (l/h) [16].

4.2 Design emission uniformity (EU_d)

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

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

Where, EU_d= uniformity of design emission, (%), C_V= coefficient of variation, N=number of emitters for each plant, q_{min}=minimum flow rate of emitter, l/h, q_{ave}= average flow rate of emitter, l/h[17]

4.3 Coefficient of variation (C_v) and Statistical uniformity

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

Where, C_v = Coefficient of Emitter flow variation, S = standard deviation of the emitter flow [17]. the guidelines for classifying the manufacturer's coefficient of variation shows in Table 1.

Table 1: Classification of coefficient of variation [18].

coefficient of variation C_v	Clarification
<0.05	Excellent
0.05- 0.07	Average
0.07-0.11	Marginal
0.11- 0.15	Poor
>0.15	unacceptable

$$\boldsymbol{SU_C} = (\mathbf{1} - C_v) * 100 \quad (5)$$

Where, SU_c =statistical uniformity coefficient %.

General requirements are 90% or greater (excellent), 80% to 90% (very good) ,70% to 80% (fair), 60% to 70% (poor) less than 60% (unacceptable) [9].

4.4 Emitter flow rate variation(q_{var})

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

Where, q_{var} = Variation in emitter flow, %, q_{min} = minimum flow rate of emitter, l/h, q_{max} = average emitter flow rate, l/h

General standards for q_{var} values are: 10% or less (desired) and 10% to 20% acceptable and above than 25%, not acceptable [19].

4.5 Pressure head variation h_{var}

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

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

4.6 Efficiency of application

The efficiency of application is described as the ratio of water needed in the root region to total quantity of water used, and can be to the expressed as,

$$E_a = \frac{q_{min}}{q_{avg}} * 100 \quad (8)$$

Where, E_a =application efficiency, %, q_{min}= minimum flow rate for emitter, l/h, q_{avg}= average flow rate of emitter, l/h [17].

5. HEAD – Discharge relationship

The relationship of head discharge for emitters is expressed by the equation

$$q = K_d * H^X \quad (9)$$

Where:

q = emitter flow rate, l/hr.

K_d = Coefficient of discharge, which is a constant of proportionality characterizing each emitter.

H = working pressure head at the emitter, m

x = exponent of emitter discharge.

The value of x is an indicator of the sensitivity of the emitter to pressure discharge. The smaller the x value, the less the flow rate is affected by pressure variations. Value of x differs from 0 to 1, depending on the design of the emitter. The observed q and H data were plotted via Excel, and the best suited model with the maximum R^2 was established. If x lies between 0 and 0.4, the pressure compensating drippers are labeled and if x is greater or equal 0.5, the drippers are classified as non-pressure compensating [21].

Figure 4: Measurement of the discharge from the drippers.

Results and Discussion

Tests carried out on soil samples showed that the soil is sandy and this type of soil is proper for cultivation of palm. Sandy soil enables a fast absorption of plants by free flow of water within its soil formation as stated by Ankidawa and Zakariah[12] .Keller and Bliesner [21] mentioned that sandy soils are suitable for drip irrigation system. Different criteria for evaluating the performance of the drip irrigation system, field emission uniformity (EU_F), absolute emission uniformity (E_a), design emission uniformity (EU_d), coefficient of flow variation (C_v), coefficient of statistical uniformity (SU_c), emitter flow rate variation(q_{var}), pressure head variation (h_{var}) and application efficiency (E_a) were calculated for each lateral line as shown in Table 2.

It is observed from Table 2 that the Field emission uniformity (EU_F) for the 4 lateral lines was falls within the allowable rang 90% or more, which was specified with Merriam and Keller [14] and Al-amoud [22], Keller and Karmeli [15], Ankidawa and Zakariah[12] and Priya et al [23] .Absolute emission uniformity (EU_a) of the system ranged from (95% to 98%), with average 96.25%, which can be categorized as excellent. The Absolute emission uniformity appears similar to that obtained by Priya et al [23]. Design emission uniformity (EU_d) of the system ranged from (94% to 97.5%), with average 95.9% which can be categorized as excellent. On the basis of the coefficient of variance, all lateral lines are classified as excellent, as the value ranges between (0.015-0.032) and the average is (0.026) according to what was mentioned by Soloman [18] and Keller and Bliesner [21].The statistical uniformity factor (SU_C) is closely related to uniformity of the system. It is used to show uniformity of the system. The high value of (SU_c) shown that the irrigation system has excellent performance with values ranging between (96-98) % and the average of (97%). Arya et al [17] reported the statistical uniformity factor over 90%which is in agreement with the present study. The variation in the lateral emitter flow rate was found to be lower than the maximum variation in discharge which allowed by 10 per cent as indicated by Michael [20]. As the value ranges between (4%-8.28%) and the average is (6.85%). Priya et al [23] shows similar finding for variation in the lateral emitter flow rate.

The variation in the pressure head at the head and at the end of the lateral lines was found to be lower than the maximum variation of allowed pressure. The maximum pressure variation allowed as indicated by Michael [20] is 20%. As the value ranges between (13.63-20) % and the average is (16.98%) The variation in the pressure head appears similar to that obtained by Pragna [19]. .Emission efficiency (E_a) of the system ranged from 94% to 98.5% with average 96.5% which indicate the system is good performance.

Table 2. Performance parameters to assess drip irrigation system in the study area.

No. of lateral	EU_F %	EUa %	EU_d %	C_v	SU_C %	q_{var} %	h_{var} %	E_a %
1	96	96	95	0.029	97	6.84	13.63	96.5
2	98	98	97.5	0.015	98	4	20	98.5
3	95	96	94	0.032	96	8.28	14.29	94
4	97	95	97	0.029	97	8.27	20	97
Average	96.5	96.25	95.9	0.026	97	6.85	13.63	96.5
Evaluation	Allowable	Excellent	Excellent	Excellent	Excellent	Allowable	Allowable	Good

Table (3) shows that the discharge from the drip devices decreases as the operating pressure decreases. A logarithmic relationship between pressure and discharge of all lateral lines was developed. The relationship of discharge and pressure of lateral line is shown in Fig. 5. The R^2 value for every dripper discharge was 0.84 which indicates satisfactory performance. The value of (x) is (0.24) and it is between (0) and (0.4), which means that the type of drippers is compensated pressure [21]

Table (3) pressure values measured in the lateral line

Discharge(l/h)	21.9	21.1	20.55	20.4	22.5	22.05	21.9	21.6	23.55	23.25	22.65	21.6	21.45	20.1	20.25	**19.95**
Pressure (m)	11.22	11.22	10.2	9.69	15.3	13.5	13.26	12.24	14.28	13.7	13.5	12.24	10.22	8.9	8.4	**8.2**

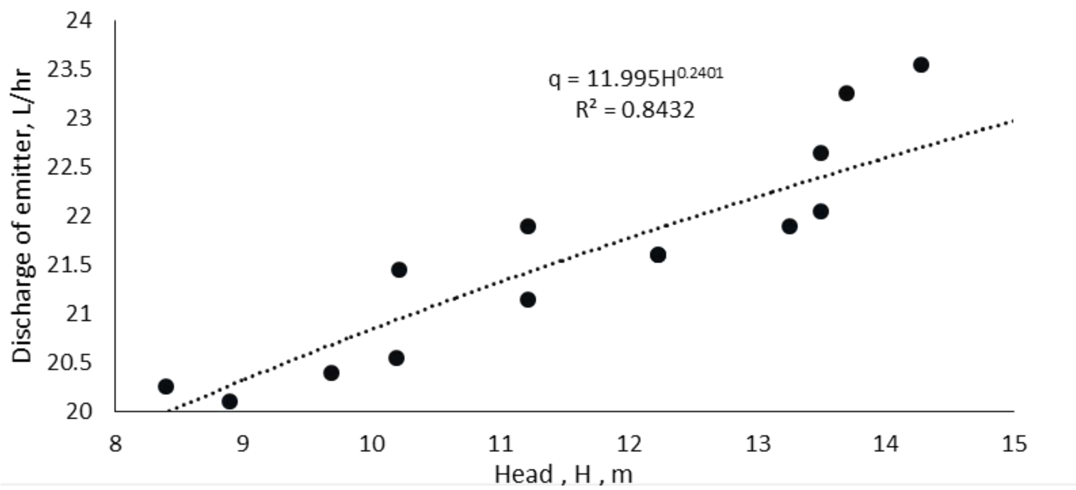

Figure (5) Relation between pressure and discharge.

Conclusion

The climate of Iraq is characterized by being semi-tropical and semi-arid. Although the country was rich in water supply until climate change and the construction of many dams on the Tigris and Euphrates rivers in neighboring countries contributed to water shortages and poor water quality. Therefore, water resources management should be improved and water consumption reduced. The drip irrigation system is considered one of the most important of these methods because it is highly efficient in using water compared to irrigation methods, and because of the expansion of the agricultural area that uses the drip irrigation system in Karbala Governorate which requires detailed studies on its efficiency. Therefore, an evaluation of the drip irrigation system was conducted at Fadak Farm in Karbala, Iraq. The result of particle size analysis shows that the type of the soil is sandy; this kind of soil is suitable for the Date Palms The results of different parameters like Emissions uniformity in field ($\boldsymbol{EU_f}$), uniformity of design emission ($\boldsymbol{EU_d}$), efficiency of application ($\boldsymbol{E_a}$), statistical uniformity coefficient ($\boldsymbol{US_c}$) was found to be above 90% which refer to that the drip irrigation system was designed on correct scale and dimensions. The results of both the coefficient of variance ($\boldsymbol{C_v}$), emitter flow rate variation ($\boldsymbol{q_{var}}$) and pressure head variation ($\boldsymbol{h_{var}}$) of drip irrigation system for the drip irrigation system are within the permissible limits. Therefore, the performance of the drip irrigation system is good. The data also show that the drip irrigation system operated well, as the EU values exceeded the 90 percent criteria.

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