Field evaluation of drip irrigation systems in Saudi Arabia

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Abstract

Drip irrigation has become a well-established method for irrigating high-value crops in regions, where water resources are scarce and/or expensive. In Saudi Arabia, the use of drip has increased fivefold since the 1990s, and now due to the rapid increase in the use for drip irrigation system in the fields and greenhouses in recent years in most agricultural regions in the Kingdom has caused the availability of many drip irrigation components and products in the local market made by different manufacturers. These devices differ in their qualities and standards. Hence, the field evaluation of drip irrigation systems in the fields and its components (i.e. emitters) is essentially required for standing the efficiency and performance of the system and these devices during irrigation.

This study was mainly focusing on evaluating 10 drip irrigation systems under field operation located in different farms in Riydh region of Saudi Arabia. Also, the study included a survey study for 50 drip irrigation systems distributed on a number of farms in the most agricultural regions in Saudi Arabia using drip irrigation systems. Results of field evaluation show that the irrigation performances are mostly lower than the accepted values for most evaluated systems and that the ten systems were varied in their uniformities of the applied water.
Keywords: drip system, water uniformity coefficient, emitter clogging, field evaluation, water distribution, water applied, Saudi Arabia.

1 Introduction

With population growth in the world, the demand of water is increasing and in many parts of the world there are major concerns regarding the sustainability of water resources for irrigated agriculture. Hence, the necessity for conservation of

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water resources increases, particularly in countries of limited water supply, where the agricultural irrigation has traditionally been the major water use sector in these areas, usually in the range of 80 to 90%. There is widespread acceptance that part of the solution lies in improving agricultural productivity and water use efficiency, and obtaining more “crop per drop” (FAO [1]). For this reason, drip (i.e. drip) irrigation is being heavily promoted, often by regulators and governments as well as the drip industry. Compared to traditional surface or overhead methods, drip irrigation offers the potential for greater water use efficiency (Al-jamal et al [2]) and has often been reported to produce crops of higher yield and quality (Mantovani [3]). Despite its higher costs. These characteristics make drip an attractive option in regions where irrigation water resources are scarce and/or expensive. Therefore, the number of drip irrigation systems has increased rapidly in the last two decades in the Kingdom of Saudi Arabia as automatic and modern irrigation systems.

To understand the current state of the drip irrigation sector in Saudi Arabia, it is useful to briefly consider how it has evolved over the last two decades. Drip irrigation was introduced commercially into the glasshouse sector in the 1980s. Its use spread into outdoor soft fruit, notably on orchard fruit and later into date palm trees, where high returns could justify the high capital investment. In the mid 1990s there was a growing interest in the use of drip for field-scale vegetable production due to product improvements and the introduction of low-cost drip tape. Its appropriateness for specific crops such as tomatoes was tested in a number of commercial small-scale field trials. However, these did not lead to widespread use on field vegetables, because of its relatively high cost then compared to center pivot sprinkler irrigation. During the 1990s there was significant growth in the amenity and landscape sectors, alongside continued expansion in the horticultural sector, underpinned mainly by consumer demand for salads and other rich vegetable crops. More recently, there has again been growth in the field-scale vegetable sector.

Drip or Drip irrigation system is widely used nowadays, in many parts of the country, due to the many advantages that the system offers, compared to other irrigation methods, its potential for conserving water in a country suffers shortage in water resources, energy and labor in addition to the reported results of higher yield and better qualities of irrigated crops (Bralts [4]. Proper system design, management and maintenance are essentials for higher Irrigation efficiency (Bucks et al [5]). Although nonuniformity of water distribution by a drip system (low efficiency), may be attributed to many factors, the hydraulic characteristics of emitters are considered the most important of these factors (Bucks and Davis [6]). The variation in water distribution by emitters may occur due to pressure changes, manufacturing variations, emitter sensitivity to clogging, temperature effect and others.

Therefore, the improvement of irrigation water management is becoming critical to increase the efficiency of irrigation water use and to reduce irrigation water demands. Drip irrigation evaluation in the field under operating conditions is very important to ensure that the desired emitter discharge uniformity required for the system design is met, and to see whether the system could be operated efficiently. Also the results of an evaluation could be used by the maintenance personnel to determine the proper operation of the system and to suggest any maintenance action if required (Bucks et al [5]).

Numerous of investigations and works has been made on the surface distribution of water from emitters (Christiansen [7]; Decroix and Malaval [8]; Merriam and Keller [9]; Karmeli [10] and Zhu et al [11]) and stated the procedures of sprinkler and emitters distribution testing above soil surface (Merriam [9] and ASAE [12]). A necessary step before calculating an applied water distribution parameter is the accurate measurement of applied water from sprinklers using catch cans or collectors (Karmeli et al [13] and Sporre-Money et al [14]). Procedures to determine the distribution of water from different sprinkler systems are given in ASAE Standard (ASAE [12]). The flow characteristics of most emitters are described by the following equation (Merriam and Keller [9] and Karmeli [10]):

$$q = b h^{\beta} \tag{1}$$

where,
q = Emitter discharge rate (liter/hr)
b= Emitter discharge coefficient
h = Pressure head at the emitter (kPa)
β = Emitter discharge exponent.

The numerical presentation for the amount of variations in emitter flow rate due to manufacturing processes could be evaluated by the coefficient of manufacturing variation (Solomon [15]), using the following equation:

$$C_v = \frac{S_d}{q_a} \tag{2}$$

$$S_d = \sqrt{\frac{q_1^2 + q_2^2 + \ ..., \ q_n^2 - nq_a^2}{n-1}} \tag{3}$$

where,
C_v = Coefficient of manufacturing variation
S_d = Standard deviation of the discharge rates (liter/hr)
q1,q2, ..,qn = discharge of emitters tested (liter/hr)
q_a = average discharge rate of all the emitters tested (l/hr)
N = Number of emitters tested.

In order to determine whether the system is operating at acceptable efficiency, evaluate the uniformity of emission, which is dependant on the pressure variation at emitters and the coefficient of manufacturing variation, C_v, and could be calculated by the following equation (Wu et al [16]):

$$Eu = \frac{q_n}{q_a} \times 100 \tag{4}$$

where:

Eu = The Emission uniformity (%)
N_p = Number of emitters tested

q_n = average rate of discharge of the lowest one-fourth of the field data emitter discharge readings (l/hr)

q_a = average discharge rate of all the emitters tested (l/hr)

A simplified way to quickly determine a measure of uniformity is to calculate the emitter flow variation (q_{var}) using the following equation:

$$q_{var} = \left(1 - \frac{q_n}{q_m}\right) \times 100 \qquad (5)$$

A key element in the design of drip irrigation systems is the close balance between the crop water requirement and the emitter discharge. To properly maintain this balance, it is important that the discharge along a lateral have high degree of uniformity. Quantification of the uniformity is given by the design emission uniformity (EU_D)

$$EU_D = \left(1 - \frac{1.27 \times C_v}{\sqrt{N_p}}\right) \times \frac{q_n}{q_a} \times 100 \qquad (6)$$

where:

N_p= number of point source emitters per emission point.

Since the drip irrigation systems have very low flow rates and extremely small passages for water. These passages are easily clogged by mineral particles and organic debris carried in the irrigation water and by chemical precipitates and biological growths that develop within the system. The result of clogging is either the complete or partial stoppage of flow through clogged components (Wu et al [16]; Bucks et al [5] and Bucks and Davis [6]). Therefore, the improvement of irrigation water management is becoming critical to increase the efficiency of irrigation water use and to reduce irrigation water demands. The field evaluation of irrigation systems and in particular drip irrigation systems is essentially required for standing the efficiency and performance of the system during operation. The evaluation data can be useful in indicating any defects regarding system operation, water distribution and water losses (Karmeli [10] and Solomon [15]). Also, the evaluation of the system performance in the field will indicate both the location and magnitude of water losses that are occurring, and then determining how to improve the irrigation system and/or its operation. This problem has a great influence on water availability and conservation and hence on the water resources planning on local and national levels. The objective of this field investigation is to evaluate ten drip irrigation systems under operating conditions in different farms in Riyadh region and to determine their indexes performances and the coefficient of manufacturing variation, and also, to report the most problems are facing the drip system users in Saudi Arabia farms.

2 Materials and methods

Field experiments were conducted on ten drip irrigation systems randomly selected from farms and greenhouses in Riyadh region of Kingdom of Saudi

Arabia, to evaluate their water distribution uniformity and efficiency under operating conditions.

The distribution of water application depths and discharges from emitters along the lateral were measured using ASAE Standards (ASAE [12]). Specific procedures have been established so results from different fields are comparable (Merriam and Keller [9]). These procedures are based on making measurements of emitter discharge along four lateral lines on a sub main: one at the inlet, one at the far end, and two in the middle at the one-third and two-thirds positions. Four positions are tested on each lateral: one at the inlet, one at the far end, and two in the middle at the one-third and two-thirds positions. This gives a total of 16 measurement positions. Measurements of emitter discharge are made at each measurement position for two adjacent emitters. This is done by measuring the flow volume collected in a graduated cylinder over a one-minute period. The average discharge, minimum discharge and coefficient of variation are calculated using data from the 16 positions. Also, the coefficients of uniformity of water distribution from emitters were determined for each drip system.

Also, a survey study for more than 50 farms using drip irrigation systems located in different regions of Saudi Arabia was carried out. This study was mainly focusing on evaluating the problems and the management of these drip irrigation systems under field operation.

3 Results and discussion

The emitter discharges along each lateral for the four lateral lines on a submain were measured and calculated for each individual drip system in ten farms, and the results are shown in figure 1. The discharge distributions along the lateral line were noticed to be variable as shown in the figure for each drip system. The variation of emitter discharge in a drip system is the result of a variety of factors. The primary factor is hydraulic design, other important factors are emitter type and emitter plugging. It was noticed during measurements there was pressure variation and emitter plugging in some emitters at different farms, also the emitters used in these farms were different in type, age and manufacturers. Also, the average discharge for the ten drip systems were compared and plotted in figure 2. It can be noticed that there was high variation in the average discharges between the ten drip systems evaluated in these farms.

Also, to investigate the emitter flow variation between these drip system, the average discharge and minimum discharge and coefficient of variation are calculated using data from the 16 positions and equations (2) and (3). The obtained curves are shown in figures 3 and 4. The results of flow variation can be used as a simple way to judge the water distribution uniformity from emitters. The general criteria for the emitter flow variation are (a) 10% or less—desirable; (b) 10 to 20%—acceptable; and (c) greater than 20%—not acceptable (Bralts [4]). From figure 3 it can be said that the emitter flow variations (q_{var}) are not acceptable for most drip system evaluated. Also, from figure 4) the system coefficient of manufacturing variation (C_v) for each system for ten drip systems was determined and shown in figure 4). Standards have been developed by the

ASAE to classify emitters based on the value of coefficient of variation. According to this classification, the emitters vary in the values of C_v, and range from 0.03 with excellent quality to 0.35 with an unacceptable quality, which will result in high discharge variations from emitters.

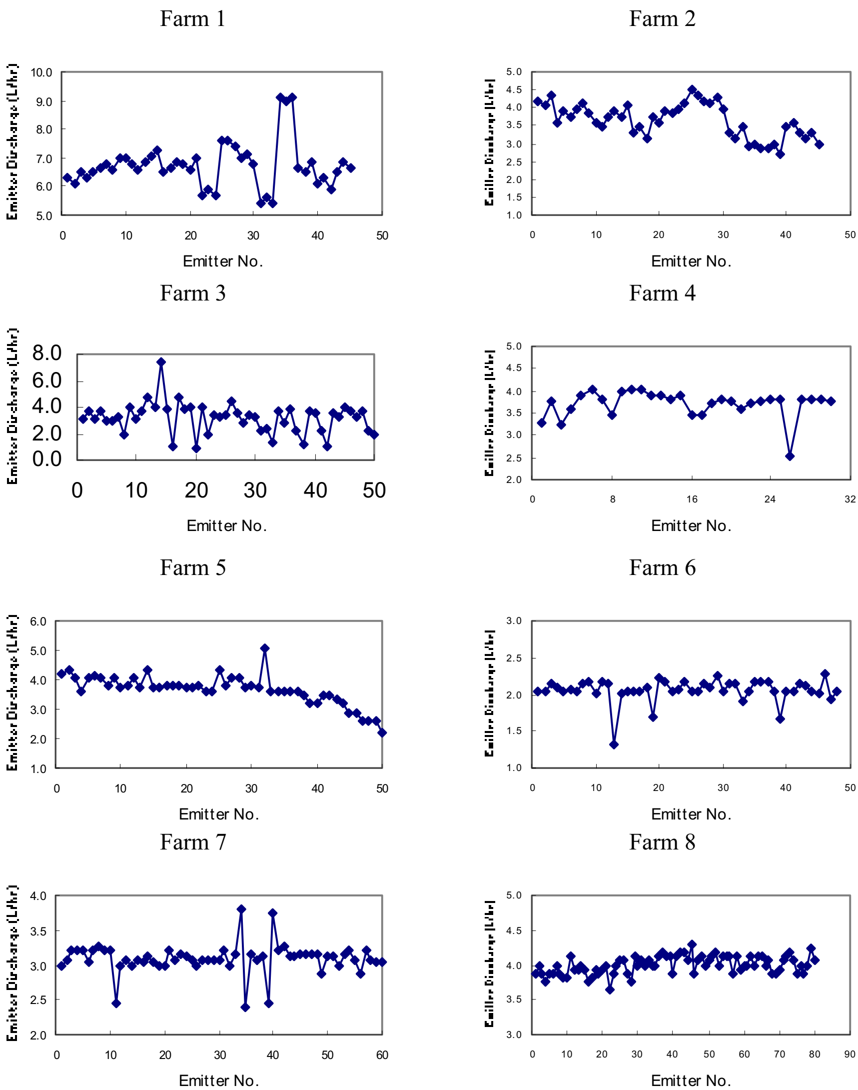

Figure 1: Emitter discharge distribution patterns along the lateral line from different farms.

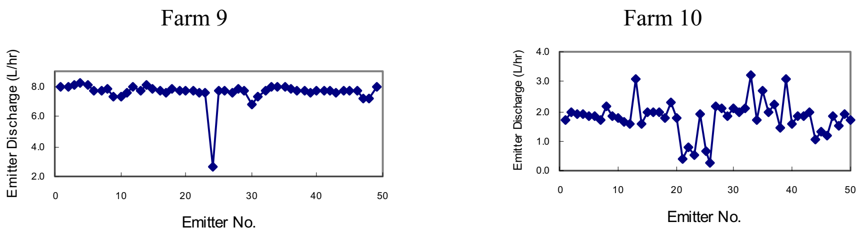

Figure 1: (cont.)

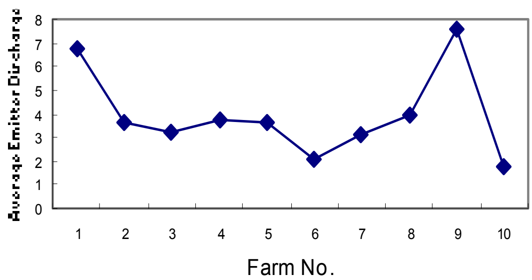

Figure 2: The average discharge measured from ten farms.

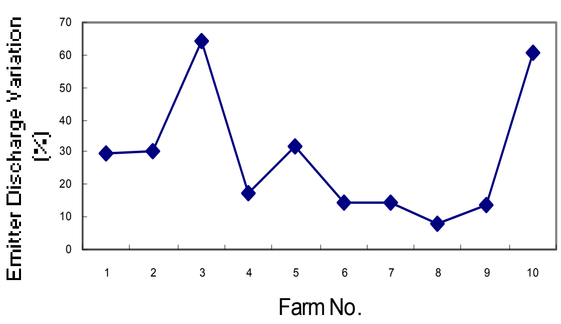

Figure 3: The emitter discharge variation (%) from tem farms.

Also, the uniformity of water distribution from each system emitters can be evaluated by computing the emission uniformity (*Eu*) and the design emission uniformity (EU_D). The *Eu* and EU_D were determined for each system emitters using equations (4) and (5), and the results were presented in figures 5 and 6. It can be noticed from the figures that the values of *Eu* and EU_D for the evaluated drip systems were ranged from 54.42% to 96.05% for the *Eu* and from 30.07% to 92.34% for EU_D respectively. To judge the drip system performance and water distribution from *Eu* and EU_D values, the ASAE developed standards to classify the *Eu* and EU_D values. General criteria for *Eu* values for systems which have been in operation for one or more seasons are: greater than 90%, excellent; between 80% and 90%, good; 70 to 80%, fair; and less than 70%, poor. Therefore, the performance of each system at each farm differs from one system to another and their water distribution also varies.

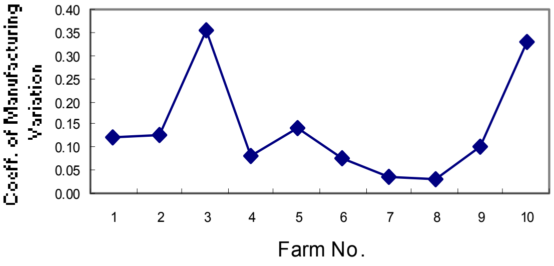

Figure 4: Coefficient of manufacturing variation fro ten farms.

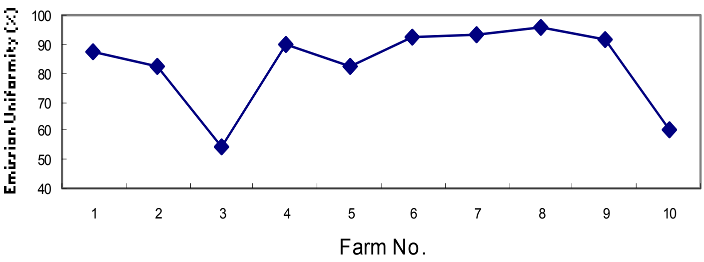

Figure 5: Emission uniformity (EU) for ten drip systems.

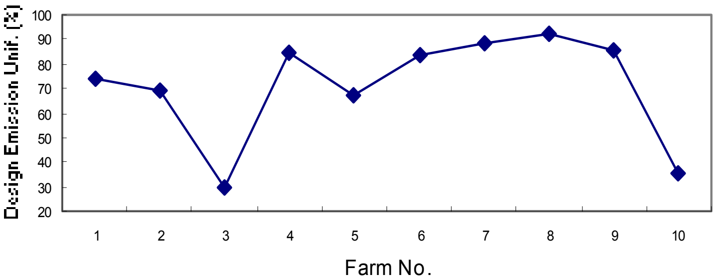

Figure 6: Design emission uniformity for ten drip systems.

Also, the survey study results showed as presented in figure 7 and figure 8 that the number of maintenance and field evaluation at these farms. Generally, it can be noticed that maintenance for the components of drip system is poor, and there was no evaluation for most systems at these farms as can be seen from the figure. Also the survey study showed that the major problems are facing farmers with drip systems are emitter and filter clogging, water leakage at emitter bases and the need for continues maintenance.

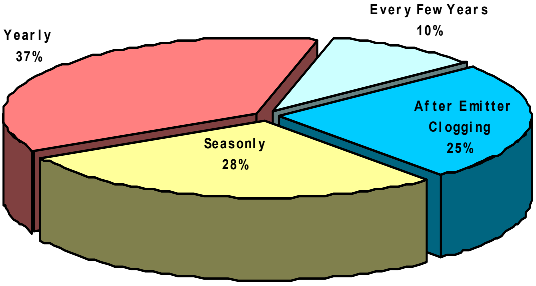

Figure 5: The occurrence of maintenance for drip systems at the farms.

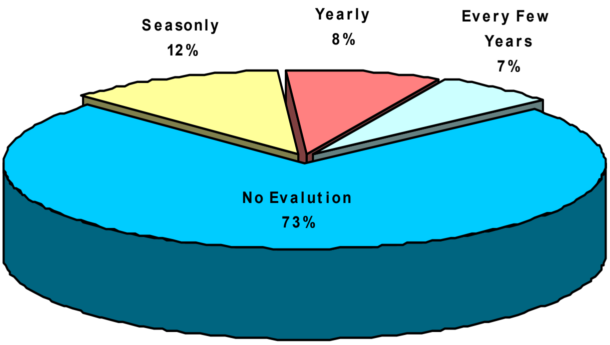

Figure 6: The occurrence of field evaluation of drip systems at the farms.

4 Conclusions

The study was conducted to investigate the performance and water distribution from ten drip irrigation systems used by local farmers irrigating crops. It was found that the ten systems were varied in their uniformities of the applied water. Also, results of field evaluation show that the irrigation performances are mostly lower than the accepted values for most evaluated systems. The causes of non-uniformity and low efficiency could be related to some factors such as, pressure variation in the system, in correct system design and emitter discharge variation. The generated results are expected to be helpful to the farmers and irrigators to make the correct maintenance to increase the irrigation system efficiency.

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