Plant Archives Vol. 19, Supplement 2, 2019 pp. 554-561 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

THE HYDRAULIC EVALUATION OF DRIP IRRIGATION SYSTEM BY HYDROCALC MODEL UNDER DIFFERENT DRIPPER TYPES AND LOW QUALITY WATER

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Abstract

A Laboratory experiments were conducted at the department of Water Relations and Field Irrigation (WRFI), Agricultural Division of National Research Centre (NRC), El Dokki, Cairo, Egypt to carry out hydraulic evaluation by HydroCalc model for three dripper types and to select the best types for using in the field experiments at NRC farm. Factorial RCB design with three replications comprising three levels of water salinity (405, 1500, 3500 ppm), Three types of drippers as follows: On-line Turbo Dripper (OTD), Built-in Dripper (BD-GR), and Pressure Compensating Dripper (PCD) under Three pressure head levels 0.8, 1.0, and 1.2 bar. From the obtained data by HydroCalc model, the power equation and R^2 values of the relationship between pressure head (bar) and flow rate (l/hr), the best was PCD and (BD-GR) at using water salinity 405, 1500, and 3500. In cases of using PCD, and (BD-GR) at using water salinity 405, 1500, and 3500 were the highest in application efficiency, distribution uniformity, the rank of dripper types can be in the following order PCD < (BD-GR) < OTD, there are significant differences between all values of dripper types. But in respect to distribution uniformity, there are significant between (BD-GR) and other dripper types, and no significant differences between OTD and (BD-GR) types. The coefficient of variation (CV), the rank of dripper types can be in the following order OTD < (BD-GR) < PCD. We can notice that no significant differences between all dripper types. It could be concluded dripper types of OTD and (BD-GR) at using water salinity 405, 1500, and 3500 were the best for using and could be recommended to using them the field research work.

Keywords: Hydraulic Evaluation, HydroCalc Model, Uniformity Coefficient, Coefficient of Variation, Dripper Type, Water Salinity.

Introduction

The efficiency of the irrigation system and water use efficiency are the most important factors in the design and management of micro-irrigation system such as drip irrigation systems, and that the increase in crop production is the most important goal and the big investment on farms and smallholdings alike. The important device in drip irrigation is the dripper. The uniformity in flow rate from drippers is affected due to pressure variation, manufacturing variation, temperature variation of the flowing water and dripper clogging (Mansour *et al*., 2015).

Drip irrigation has many benefits, but one of the most serious problems in the system is dripper clogging. It is attributed to several factors and is classified into physical, chemical and biological properties (Gilbert and Ford, 1986). Salinity could be one of the main causes of dripper clogging in drip irrigation system, which build up either from irrigation water and/or fertigation process. Dripper clogging depends upon the type of dominant salts in water used andits content, especially the basics salts (Ca; Mg). Dripper clogging depends upon its water discharge capacity. The drippers with large nominal discharge, self-flushing and pressure compensating features recorded less flow rate reduction than less nominal discharge drippers.

Choosing drippers with the higher discharge rates must be important because the higher percentage of clogging was observed in smaller discharge rate dripper than higher discharge one (Bozkurt and Ozekici, 2006). The composition of water is important when the water contains high amount of soluble cations (Ca, Mg, Fe and Mn) especially with SO_4 and/or HCO_3 anions owing to high risk of dripper clogging (Sanij *et al*., 2001).

Uniform application of water in agriculture has a major impact on crop production and net farm income. Water is saved when irrigation uniformity is improved. Ideally, all drippers in micro irrigation should deliver equal quantity at irrigation process. Number of studies on drip irrigation system with use of saline or sodic water for irrigation was done. The water having high pH or EC was responsible for clogging of drippers. Hence, present study was taken to study was conducted.

Distribution Uniformity, DU In addition to the issue of how well the applied water is used is the important issue of how uniformly this water is distributed to the crop (or the soil, for a pre irrigation). A non-uniform distribution not only can deprive portions of the crop of needed water, but, furthermore, can over irrigate portions of a field, leading to water-logging, plant injury, salinization, and transport of chemicals to the ground water (Solomon, 1983). Distribution uniformity, DU, is defined here as a measure of the uniformity with which irrigation water is distributed to different areas in a field. Thus for defining DU, the term accumulated water is used here to include the infiltration, canopy interception, and reduction of transpiration during irrigation. Before DU can be defined for a distribution, the distribution itself must be carefully defined, in order that it be truly universal, that is, applicable to all crops-trees, vines, vegetables, field crops, turf, and so forth. The results are further elaborated in order to evaluate the effect of water salinity and operation pressure on the performance of selected drippers.

The aim of this research to investigate the hydraulic evaluation by HydroCalc model for three dripper types and to select three types for using in the field experiments at NRC farm. Factorial RCB design with three replications comprising three levels of water salinity (405, 1500, 3500 ppm), Three types of drippers as follows: On-line Turbo Dripper (OTD), Built-in Dripper (BD-GR), pressure compensating dripper (PCD), Pressure compensating and

Self flushing dripper under three pressure head levels 0.8, 1.0, and 1.2 bar.

Material and Methods

Field experiments were carried out in the Experimental Farm of Agricultural Production and Research Station (APRS), National Research Centre (NRC), El-Nubaria Province, Egypt, sandy soil (latitude 30.8667N, and longitude 30.1667E, and mean altitude 21 m above sea level). It is deep and moderately drained and containing predominantly sand. Three types of water having different salinity (EC) (405, 1500, and3500 ppm) (0.52, 3.13, and 6.25 dS/m) were used. With these three types of dripper with discharge rate 4 l/h were used. The experiment was laid out in factorial RCB design with three repetitions.

Irrigation water of desired salinity level (i.e. 3.13 and 6.25 EC dS/m) was prepared by mixing canal water (EC=405 ppm, 0.52 dS/m) with underground water (EC= 5120 ppm, 8.0 dS/m) and stored in plastic tank of 1000 liters capacity. The tanks were placed on the terrace of N.M. College of agriculture (height 13 meters) for providing 1.25 kg/cm^2 pressure. The system was operated for 1hr, two days a week. The flow rates of an individual dripper were determined by collecting the water in the cans for 10 minute and measured the volume of water with the help of graduated cylinder. It converted in to litre per hour (lph) by multiplying with 6. Flow rate was measured at 15 days interval and periodic clogging percent of different drippers were computed and the uniformity co-efficient was worked out (**Bralts *et al.*, 1987).**

The study was conducted to evaluate performance of varying drippers in terms of emission uniformity under different operation pressures for Turnip crop.

1- Irrigation system and experimental layout:

The total area of the experiment was 270 m^2 and divided into nine main plots Layout of the experiment is shown in Fig. (1).

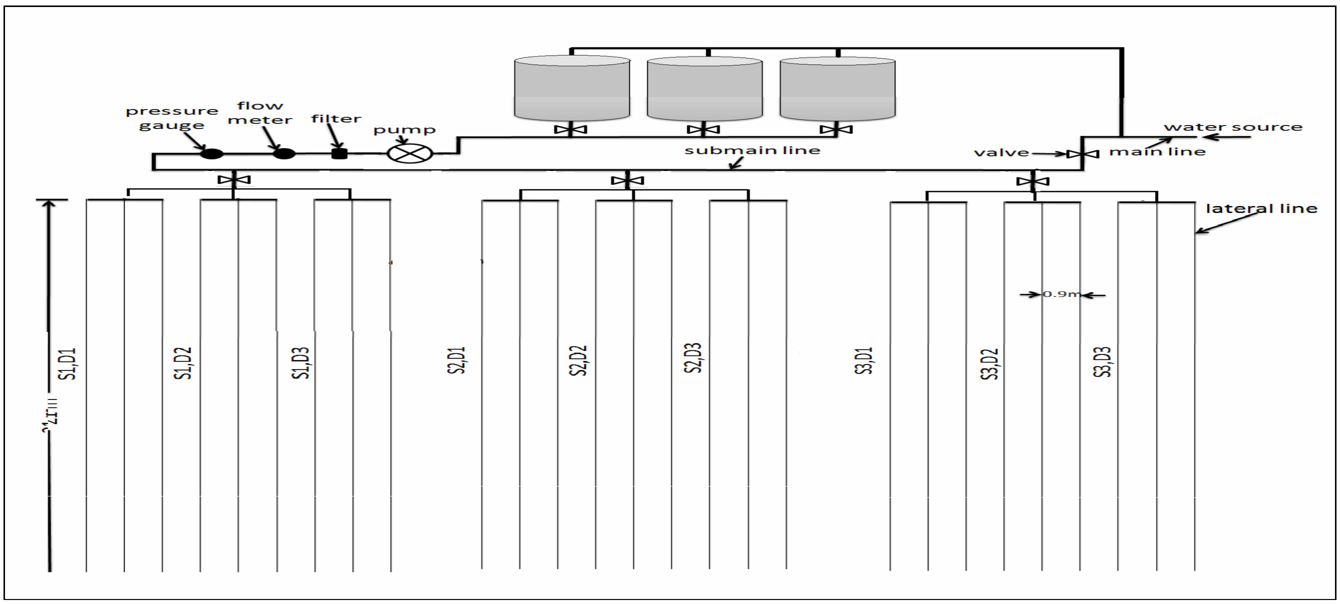

Fig. 1 : Layout of drip irrigation system

The system consists of the following components, as presented in Fig. 1.

Tank

Three Polyethylene, 1 m^3 tanks with a float inside was connected to the control head. The tanksare being filled with water through 63 mm pipe PVC - 6 bar, derived from the main line of the farm.

Control head:

It is located at the water inlet and consists of:-

- **Pump:** centrifugal electric pump (0.75HP), n ≈ 2900 rpm and discharge 3 m^3/h.
- **Filter:** screen filter 1.5" (one unit), 155 mesh, Max. Flow 7.2m^3 \ h and maximum pressure 150 (PSI).
- **Injection unit:** venturei PE of 1", rang of suction capacity 34- 279 l/h.
- **Measurement units:** spring brass non-return valve 2",

Pressure gauges, control valves and flow meter.

Main line:

PVC pipe of 63 mm diameter - 6 bar, connects the control unit to convey the water to sub main lines.

Sub main line

PVC 32 mm diameter line delivered from the main line to feed the group of the laterals which represent treatments.

Laterals:

It is 16 mm diameter PE tubes, with 30 cm apart, built in drippers of 4 lph discharge at 1bar operating pressure. Distance between laterals was 0.9 m.

Hydraulic irrigation software component:

HydroCalc irrigation software was designed to help the designer identifying the parameters of an irrigation system. The user will be able to run the program with any appropriate parameters, reviewing output and change the input data in order to conform to the preparation of an appropriate irrigation system.

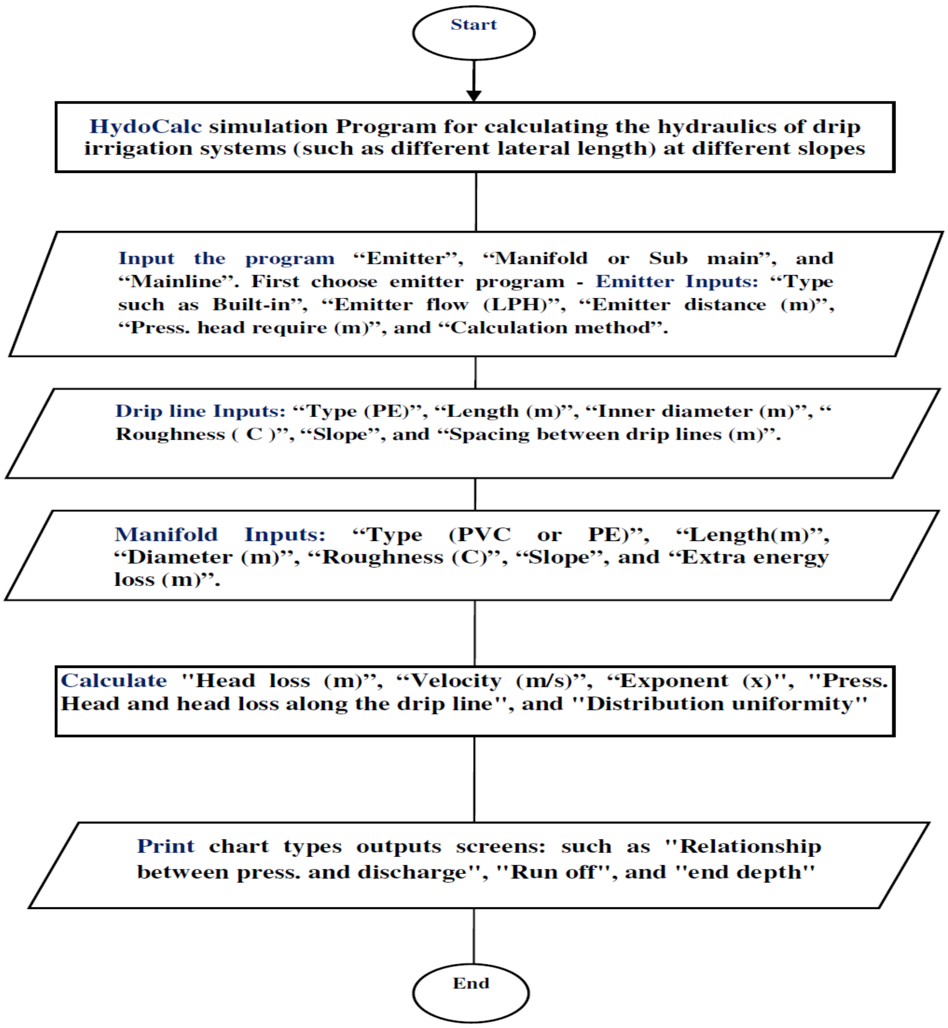

Fig. 2: Flow chart components of HydroCalc simulation program for planning, design, and calculating the hydraulic analysis of drip irrigation system at different slopes or levels.

Some parameters may be selected from the system list whereas the user according to their own needs enters others so they do not conflict with the program's limitations. The software package includes an opening main window, five calculation programs, one language setting window and a database that can be modified and updated by the user as shown in figure (1).

Fig. 1 : HydroCalc irrigation planning

Statistical analysis: COSTAT program was used to carry out Statistical Analysis. The treatments means were compared using the technique P of analysis of variance (ANOVA) and the least significant difference between systems at 5 %.

Results and Discussion

Relationship between pressure head and discharge

It is known that in a drip irrigation system is a direct correlation or positive relationship between the operating pressure and the dripper flow rate. This relationship may be affected by some changes in the physical properties of water, one of these changes is to increase the proportion of salt, which are usually found in low-quality water where salt levels vary with water depending on the purpose, which was used the water by, or that the source is the sea salt. Figures (4, 5 and 6) shown the predicted flow rate in (lph), head loss in (m) and velocity in (m/s) by the HydroCalc simulation program for surface drip irrigation system design with pressure (1.0 bar). One can notes that flow rate and velocity took the same trends, Where the value of both decreases as the value of water salinity increases with the following arrangement of the drippers OTD > BD-GR> PCD while the friction loss reverses the previous trend with respect to the degree of salinity and types of points. The greater interaction of both the rate of disposition and speed coincides with the PCD X 405 while the least interaction encountered with the OTD X 3500. On the other hand, the greater interaction of friction loss coincides with the OTD X 3500 while the least interaction encountered with the OTD X 3500.

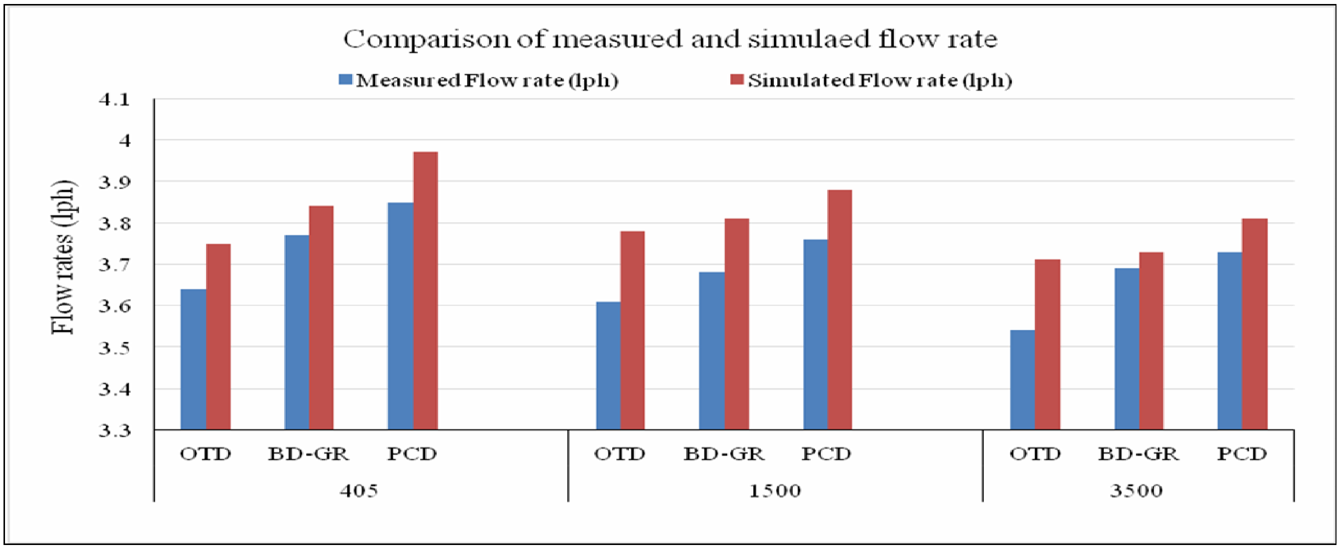

Fig. 4 : Effect of saline water and dripper type on measured and simulated flow rate

One can notice that under water salinity levels 405, 1500, 3500ppm, flow rate values obtained were (3.39, 3.75; 4.83), (3.66, 3.78; 4.14), (3.75, 3.81, 3.94, 4.13; 4.18), (3.76, 3.83; 4.23) and (3.58, 3.64, 3.85, 3.94; 3.82) at the pressure head values (0.8, 1.0, 1.4; 1.6), respectively. Maximum and minimum values of flow rate achieved with water salinity 405 ppm at 1.4 and 0.8 bar, respectively. By using (BD-GR) dripper type under the previous water salinity levels, the obtained flow rate values were (3.81, 397; 4.45), (3.66, 3.78; 4.14), (3.75, 3.81; 4.18), (3.76, 3.83; 4.23) and (3.58, 3.64; 3.96), respectively. Maximum and minimum values of flow rate achieved with water salinity 345 and 3500 ppm at 1.0 and 1.2 bar, respectively. For using pressure compensating (PCD) dripper type, the obtained flow rate values under the same water salinity levels were (3.80, 3.84; 4.02), (3.76, 3.81; 4.13), (3.65, 3.71; 4.17), (3.51, 3.57; 4.23) and (3.53, 3.78; 3.95), respectively. Maximum and minimum values of flow rate achieved with water salinity 1500 ppm at 1.2 and 0.8 bar, respectively.

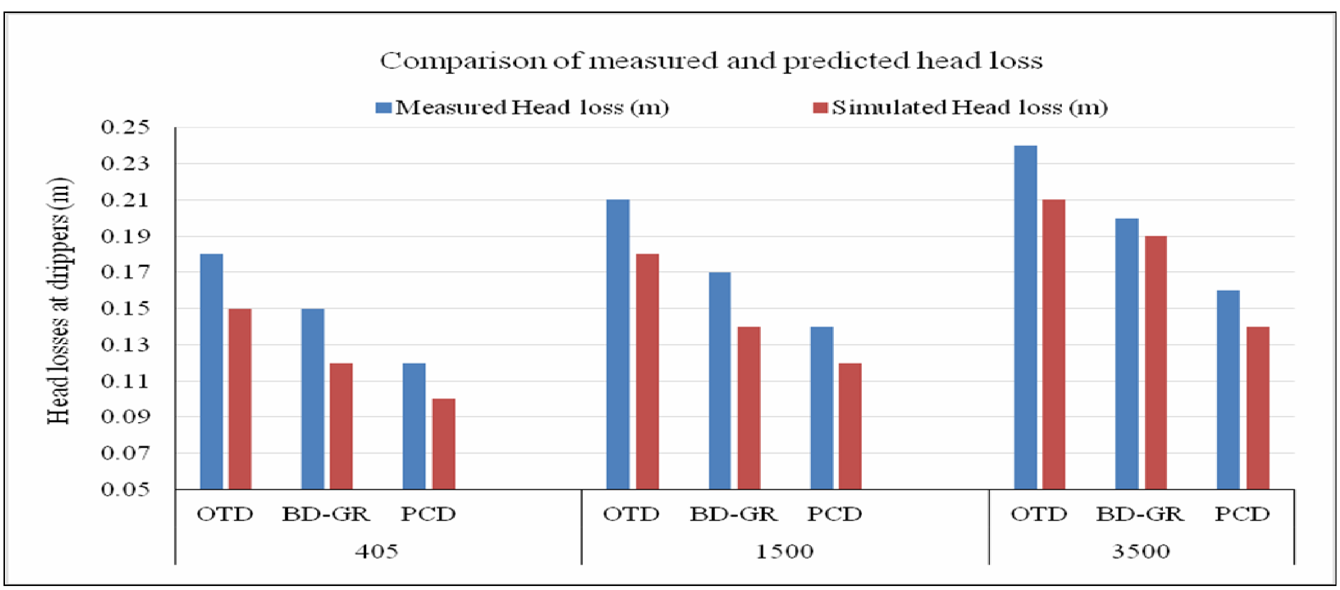

Fig. 5 : Effect of saline water and dripper type on measured and simulated head loss

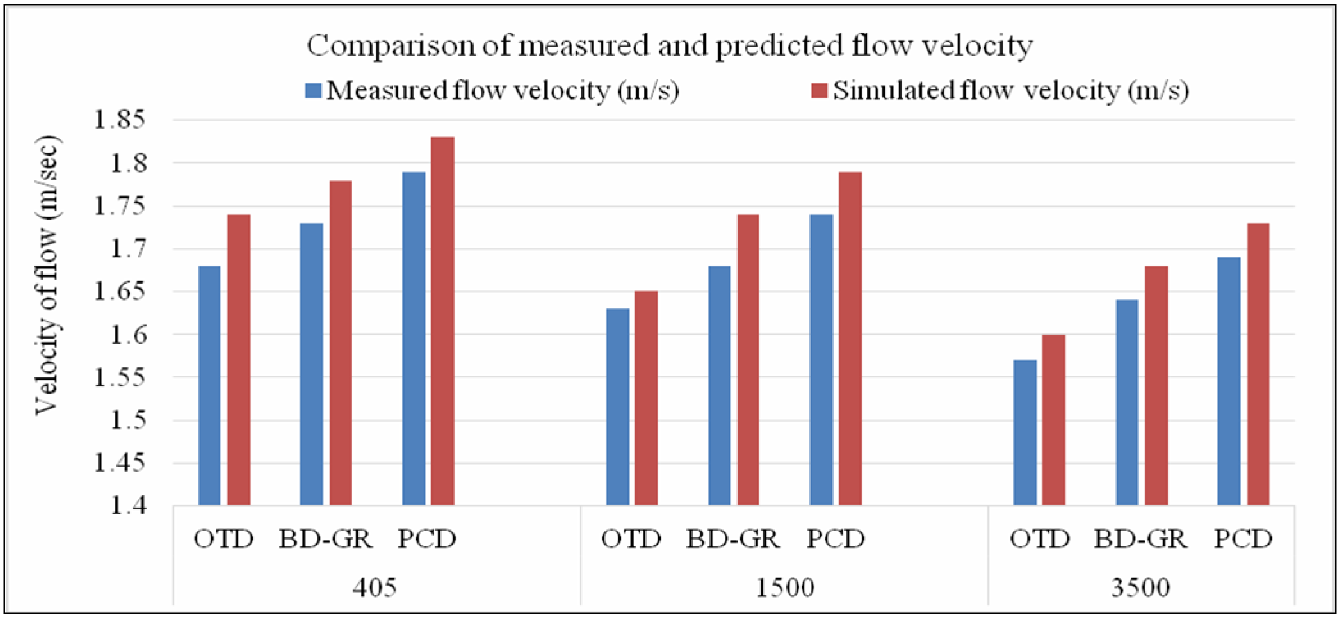

Fig. 6 : Effect of saline water and dripper type on measured and simulated flow velocity

Figures (1, 2, 3, 4 and 5) illustrates the positive relationship between pressure head and flow rate under different water salinity for OTD dripper type.

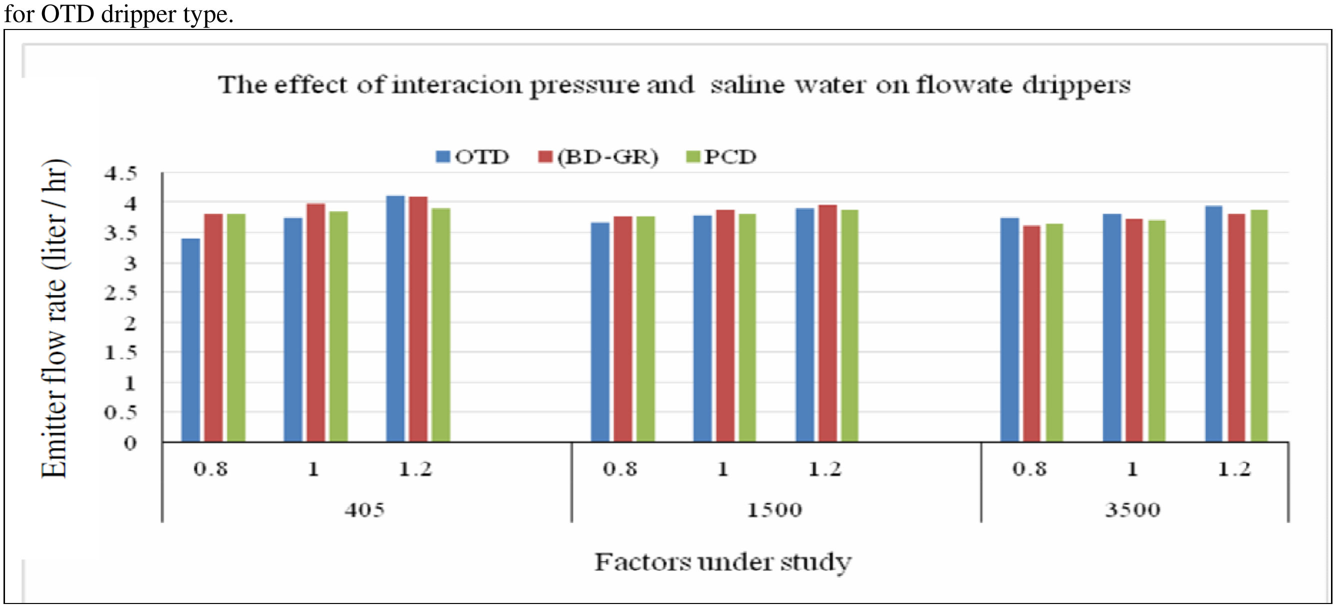

Fig. 7 : The effect of water salinity and pressure head on flow rate of on-line dripper (OTD) dripper type.

According to the resulted LSD at 5% level, there are significant differences between all values of flow rate and at all interaction. In this research work has been the use of water of varying salinity to test Three types of drippers under Three different operating pressure and dripper hydraulically tests measured the disposal of all cases, and also calculate the coefficient of variation and uniformity coefficient of each case. From figures (8, 9 and 10), we can get on the power equations and regressions values R2 of the dripper types used in the hydraulic test, the following Table (2) concludes on the equation obtained for the Three dripper types and under Three levels of water salinity.

Table 2 : Equations and R2 of the relationship between pressure head and flow rate of different Three dripper types.

Dripper type	Water salinity (ppm)	Power equation	R2
OTD	405	$y = 3.7716x^{0.5103}$	$R^2 = 0.9975$
	1500	$y = 3.792x^{0.1773}$	$R^2 = 0.993$
	3500	$y = 3.8564x^{0.1704}$	$R^2 = 0.9492$
(BD-GR)	405	$y = 3.9797x^{0.2227}$	$R^2 = 0.9861$
	1500	$y = 3.883x^{0.1716}$	$R^2 = 0.9677$
	3500	$y = 3.7347x^{0.1786}$	$R^2 = 0.9751$
PCD	405	$y = 3.8494x^{0.0741}$	$R^2 = 0.902$
	1500	$y = 3.8355x^{0.132}$	$R^2 = 0.9286$
	3500	$y = 3.7594x^{0.1853}$	$R^2 = 0.9257$

According to the power equation and R^2 values in Table (4) obtained by the relationship between pressure head (bar) and flow rate (l/hr), one can notice that dripper types of (BD-GR) and OCK at using water salinity 405, 1500, and 3500 were the best for using and could be recommended to using them the field research work.

Uniformity and coefficient of variation of testing dripper types:

Figures (8, 9 and 10) illustrate the effect of dripper type on Application efficiency, distribution uniformity and coefficient of variation under (1.0 bar) as a nominal pressure head, one can notice that for application efficiency (AE) and distribution uniformity (DU), the ranked of dripper type were PCD > (BD-GR) > OTD. According to application efficiency, there are significant differences between all values of dripper types. But in respect to distribution uniformity, there are significant between OCK and other dripper types, and no significant differences between OTD and (BD-GR) types.

According to the coefficient of variation (CV), Fig. (10) Showing that the rank of dripper types can be in the following order: OTD < (BD-GR) < PCD. We can notice that no significant differences between all dripper types.

These finding are agreement with those reported by Mansour and Aljughaiman (2012) and Tayel *et al*., (2012 a; b), Mansour, *et al*., (2015 a, b, c, d), Tayel *et al*. (2016), Pibars and Mansour, (2015), Pibars and Mansour (2016) and Mansour *et al*. (2014).

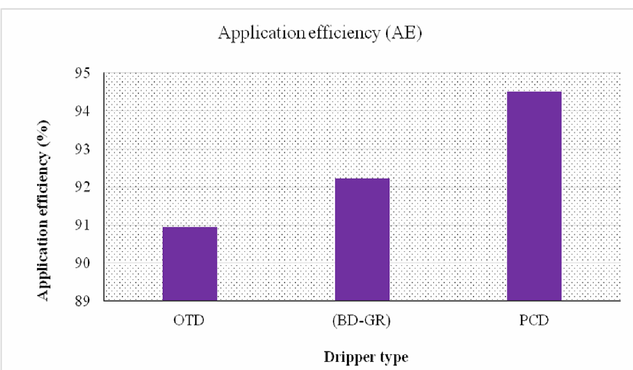

Fig. 8 : The effect of dripper type on Application efficiency under (1.0 bar) as a nominal pressure head.

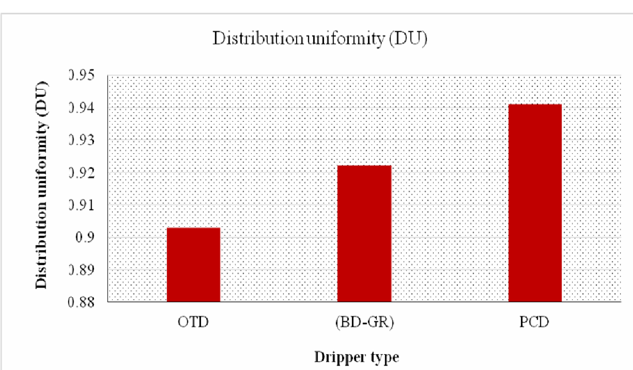

Fig. 9 : The effect of dripper type on distribution uniformity under (1.0 bar) as a nominal pressure head.

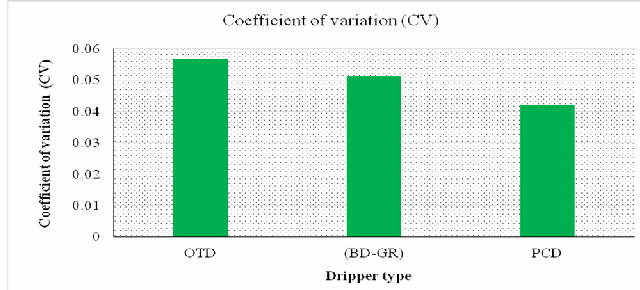

Fig. 10 : The effect of dripper type on coefficient of variation under (1.0 bar) as a nominal pressure head.

Conclusion

From the obtained data by measured and simulated by HydroCalc model, the power equation and R^2 values of the relationship between pressure head (bar) and flow rate (l/hr), the best was OTD, and (BD-GR) at using water salinity 405, 1500, and 3500. In cases of using OTD and (BD-GR) at using water salinity 405, 1500, and 3500 were the highest in application efficiency, uniformity coefficient. There are significant differences between all values of dripper types. But in respect to distribution uniformity, there are significant between OCK and other dripper types, and no significant differences between OTD and (BD-GR) types. The coefficient of variation (CV), the rank of dripper types can be in the following order: (BD-GR)<EF<PCD. We can notice that no significant differences between all dripper types.

It could be concluded dripper types of OTD and BUILT-IN-DRIPPER(BD-GR) at using water salinity 405, 1500, and 3500 were the best for using and could be recommended to using them the field research work.

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