EnergyandWaterSavingbyUsing Modified-Closed Circuitsof DripIrrigationSystem

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ABSTRACT:

The aim of this research was determine the en- ergy and water use efficiencies under the modi- fication of closed circuit drip irrigation systems designs. Field experiments carried out on trans- genic maize (GDH, LL3), (Zea Mays crop) under two types of closed circuits: a) One manifold for lateral lines or Closed circuits with One Mani- fold of Drip Irrigation System (CM1DIS); b) Closed circuits with Two Manifolds of Drip Irri- gation System (CM2DIS), and c) Traditional Drip Irrigation System (TDIS) as a control. Three lengths of lateral lines were used, 40, 60, and 80 meters. PE tubes lateral lines: 16 mm diameter; 30 cm emitters distance, and GR built-in emit- ters 4 lph when operating pressure 1 bar under Two levels slope conditions 0% and 2%. Ex- periments were conducted at the Agric. Res. Fields., Soil and Plant & Agric. System Dept., Agric. Under 0% level slope when using CM2DIS the increase percent of Energy Use Efficiency (EUE) were 32.27, 33.21, and 34.37% whereas with CM1DIS were 30.84, 28.96, and 27.45% On the other hand when level slope 2% were with CM2DIS 31.57, 33.14, and 34.25 while CM1DIS were 30.15,28.98, and 27.53 under lateral lengths 40, 60 and 80 m respectively relative to TDIS. Water Use Effi- ciency (WUE) when level slope 0% under CM2DIS were 1.67, 1.18, and 0.87 kg/m^3com-pared to 1.65, 1.16, and 0.86 kg/m^3 with CM1DISand1.35,1.04,and0.75kg/

m³withTDISwhereas with level slope 2% when using CM2DIS were 1.76,1.29,and0.84kg/m³comparedto1.77,1.30, and 0.87 kg/m³ with CM1DIS and 1.41, 1.12, and 0.76 kg/m³ (for lateral lengths 40, 60, and80 meters respectively). Water saving percent var- ied widely within individual lateral lengths and between circuit types relative to TDIS. Under slope 0% level CM2DIS water saving percent values were 19.26, 12.48, and 14.03%; withCM1DIS they were 18.51, 10.50, and 12.78%; and under slope level 2% with CM2DIS they were 19.93,13.26,and10.38%andCM1DISwere20.49,13.96, and 13.23% (for lateral lengths 40, 60, 80 meters respectively). The energy use efficiency and water saving were observed under CM2DIS and CM1DIS when using the shortest lateral length 40 meters, then lateral length 60 meters, while the lowest value was observed when us- ing lateral length 80 meters this result depends on the physical and hydraulic characteristics of the emitters, lateral line uniformity, and friction losses. CM2DIS was more energy use efficiency, EUE, water saving, and WUE than either CM1DIS or TDIS.

Keywords: Drip Irrigation; Closed Circuits; Energy Use Efficiency; Water Use Efficiency.

المستخلص:

كان الهدف من هذا البحث هو تحديد كفاءات الطاقة واستخدام المياه في ظل تعديل تصاميم أنظمة الري بالتنقيط ذات الدائرة المغلقة. أجريت التجارب الميدانية على الذرة المحورة (GDH ، LL3) ، (محصولZea Mays) تحت نوعين من الدوائر المغلقة: أ) مجمع واحد للخطوط الجانبية أو الدوائر المغلقة مع مناورة واحدة من نظام الري بالتنقيط (CM1DIS) ؛ ب) دوائر مغلقة ذات شقين من نظام الري بالتنقيط (CM2DIS) ، وج) نظام الري بالتنقيط التقليدي (TDIS) كعنصر تحكم. تم استخدام ثلاثة أطوال من الخطوط الجانبية: 40 ، 60 ، و 80 متراً. الخطوط الجانبية لأنابيب PE: قطرها 16 مم ؛ مسافة بواعث 30 سم ، وانبعاثات GR مدمجة - 4 لترات في الساعة عند تشغيل ضغط 1 بار تحت ظروف انحدار مستويين 0٪ و 2٪. أجريت التجارب في Agric. الدقة. الحقول. والتربة والنبات والزراعة. تحت منحدر مستوى 0٪ عند استخدام CM2DIS كانت نسبة الزيادة في كفاءة استخدام الطاقة (32.27 (EUE و 33.21 و 34.37٪ بينما مع CM1DIS كانت 30.84 و 28.96 و 27.45٪ من ناحية أخرى عندما كان مستوى المنحدر 2٪ مع CM2DIS 31.57 و 33.14 و 34.25 بينما كان CM1DIS 30.15 و 28.98 و 27.53 تحت الأطوال الجانبية 40 و

60 و 80 مترًا على التوالي بالنسبة إلى TDIS. كفاءة استخدام المياه (WUE) عندما يكون المستوى المنحدر 0٪ تحت CM2DIS 1.67 ، 1.18 ، و 0.87 كجم / م 3 كوم-قلص إلى 1.65 و 1.16 و 0.86 كجم / م 3 مع CM1DISو 1.35 و 1.04 و 0.75 كجم / م 3 مع TDIS بينما مع مستوى المنحدر 2 ٪ عند استخدام CM2DIS كان 1.76 و 1.29 و 0.84 كجم / م 3 مقارنة بـ 1.77 و 1.30 و 0.87 كجم / م 3 مع CM1DIS و 1.41 و 1.12 و 0.76 كجم / م 3 (للأطوال الجانبية 40 و 60 و 80 مترًا على التوالي). تباينت نسبة توفير المياه بشكل كبير في الأطوال الجانبية الفردية وبين أنواع الدوائر بالنسبة إلى TDIS. تحت المنحدر 0٪ مستوى CM2DIS كانت قيم توفير المياه 19.26 و 12.48 و 14.03٪ ؛ مع CM1DIS كانت 18.51 و 10.50 و 12.78٪. وتحت مستوى المنحدر 2 ٪ مع CM2DIS كانت 19.93 و 13.26 و 10.38 ٪ و CM1DIS كانت 20.49، 13.96 و 13.23٪ (للأطوال الجانبية 40 و 60 و 80 مترًا على التوالي). تمت ملاحظة كفاءة استخدام الطاقة وتوفير المياه تحت CM2DIS و CM1DIS عند استخدام أقصر طول جانبي 40 مترًا ، ثم الطول الجانبي 60 مترًا ، بينما لوحظت أقل قيمة عند استخدام الطول الجانبي 80 مترًا ، وتعتمد هذه النتيجة على المادية والهيدروليكية خصائص البواعث وتوحيد الخط الجانبي وخسائر الاحتكاك. كان CM2DIS أكثر كفاءة في استخدام الطاقة ، EUE ، توفير المياه ، و WUE من CM1DIS أو TDIS.

الكلمات الرئيسية: الري بالتنقيط؛ دوائر مغلقة كفاءة استخدام الطاقة؛ كفاءة استخدام المياه.

1. INTRODUCTION

Drip irrigation system cutting edge technology in irrigation has many advantages and is accompanied by some of the problems and constraints as a problem low compressor water at the end of irrigation lines subsidiary has been proposed the development of closed-circuit by adding some modifications to the traditional system of drip irrigation to overcome this problem. According to increasing areas irrigated by drip system in the Egyptian desert at high rates, too, where this approach is su- ccessful for the irrigation of fruit trees and some crops of vegetables and field crops.A. Mansour *et al.* / Agricultural Sciences 2(2010)154-177155

The unique drip irrigation system on the other that he is part of the moisten the soil only and the other parts remain dry throughout the season. This results in partial hydration many benefits and few problems. Known as the drip irrigation system so that it is adding water to the soil directly in quantities close to field capacity. It is entirely appropriate term for plant growth in the form of small droplets to the plant roots where he pays a compressor under low water ranges between 70 cm and from 15 meters through the emitters

are placed next to plants and the disposal of these rate ranges emitters of 2-16 liters/hour.

Sources of fossil fuel are being rapidly depleted and energy consumption is increasing at an exponential rate. The International Energy Outlook 2006 (IEO, 2006) projects strong growth for worldwide energy demand over the period from 2003 to 2030. The total world con- sumption of marketed energy expands from 421 quadril- lion British thermal units (Btu) in 2003 to 563 quadril- lion Btu in 2015; and then to 722 quadrillion Btu in 2030, or a 71% increase over the 2003 to 2030 period **Figure 1**.

Pimentel *et al.* [2] indicated that irrigation accounts for 13 % of the agricultural energy consumption. There have been some attempts to power irrigation systems with renewable energies, but most of the resulting sys- tems where designed for large farms and the cost for such systems is usually high. Designing successful irri- gation systems powered with renewable energies for small farms depends on many factors, such as climate, crop, crop water needs, and type of irrigation system, and the kind of the crop. More accurately, it depends on the balance between the energy demand and supply. Due to the large number of factors involved in the design process of such a system, it is not easy to conduct ex- periments to evaluate the effect of each factor so model- ing the whole process enables investigation of the effect of each factor without conducting expensive and labor intensive fieldexperiments. World-wide, various types and models of drip or mi-

cro-irrigation have evolved. Aside from the basic tech- nical differences, they differ in cost or affordability and in water distribution uniformity. Among the most cost- effective of these models is the drip kit developed by International Development Enterprises (IDE). The drip kit consists of microtube emitters inserted through plas- tic tape roll laterals connected to polyethylene sub- main pipes which in turn can be connected to a drum water reservoir. The system can be operated by elevating the drum reservoir at appreciable head, thereby eliminating the need for a pumping unit. Typical operating heads of the IDE drip kits range

from 1.0 m to 3.0 m [3]. This drip irrigation technology is suitable for developing countries because of its low cost and simplicity of design and installation. It has started gaining popularity in some upland watersheds in the Southeast Asian countries of the Philippines, Vietnam and Indonesia for vegetable production under agroforestry systems [4]. While distri- bution uniformity studies of some types of drip or trickle irrigation systems have been undertaken [5], evaluation of the performance of low-cost drip irrigation systems such as that of IDE at different heads for a given slope has not been fully explored. In fact, no rigorous study has been carried out to determine recommendable operating heads for such low-cost drip systems to generate certain levels of water distribution uniformity especially under sloping conditions. This study was conducted to determine the effect of hydraulic head and slope on the water distri- bution uniformity of the IDE 'Easy Drip Kit' and subse- quently develop mathematical relationships to characterize the effect of slope and head on water distribution uniform- itywhich can serve as the basis for optimizing water use efficiency and cropproductivity.

Pipelines are essential for the use of drip irrigation, and they need to operate at much higher pressures (typi- cally 1 - 2 bar for drip systems) and need to be strong enough to withstand up to twice the working pressure. The reason for this is that pressure surges whichare

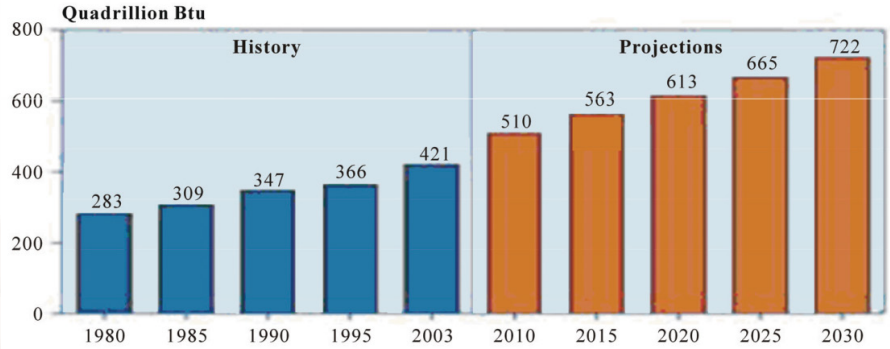

Figure 1. Global energy consumption from 1980 to 2003 and the projected consumption to 2030 in Quadrillion BTU (sources: History; International

Energy Annual 2003 [1], Projection; System for the Analysis of Global Energy Markets 2006(EIA)).

Install a pipe with the correct pressure rating to avoid the expense of repair or even replacement of a complete system. Energy is needed in pipe systems not only to pump water from the source to the pipe but also to overcome the energy losses due to friction as water flows down the pipe. If surface irrigation is used, then- properly. Predicting head losses in pipes is not an exact science and it easy to make mistakes when calculating them. In addition, losses can increase as the pipe ages and becomes rougher inside through continued use. For these reasons the losses in the distribution system should be kept low at the design stage by choosing pipe diame- ters that are large enough for friction to not dominate the operation of the system at some later date. As a guideline, energy losses in the pipes should be less than 30% of the total pumpinghead.

Energy is another word commonly used in everyday language, but in hydraulics and irrigation it has a very specific meaning: - Energy enables useful work to be done. In irrigation, energy is needed to lift or pump wa- ter. Water energy is supplied by a pumping device driven by human or animal power, or a motor using solar, wind or fossil fuelenergy

The system of energy transfer is not perfect and en- ergy losses occur through friction between the moving parts and are usually lost as heat energy (the human body temperature rises when work hard; an engine heats as fuel is burnt to provide power). Energy losses can be significant in pumping systems, and so can be costly in terms of fuel use[6].

Qualitative classification standards for the production of emitters, The emitter discharge rate (q) has been de- scribed by a power law, $q = kH^x$, where operating pressure (H), emitter coefficient (k), and exponent (x) depend on emitter characteristics [7,8]. According to the manufacturer's coefficient of emitter variation (CVm), have been developed by ASAE. CVm values below 10% are suitable and > 20% areunacceptable [9]. The emitter

discharge variation rate (qvar) should be evaluated as a design criterion in drip irrigation systems; qvar< 10% may be regarded as good and qvar> 20% as unaccept- able [10,11]. Differences in emitter geometry may be caused by variation in injection pressure and heat insta- bility during their manufacture, as well as by a hetero- geneous mixture of materials used for the production [8]. Lamm*et al.* [12] utilizes this method in calculating the distribution uniformity of drip laterals applying waste- water from a beef lagoon. Distribution uniformities ranged from 54.3% to 97.9% for the tubing evaluated.

Only a small percentage of emitter plugging can re- duce the application uniformity [13]. TaloziandHills

[14] have modeled the effects of emitter and lateral cloggingonthedischargeofwaterthroughalllaterals.

Results show that the discharge from laterals that were simulated to be clogged decreased while laterals that were not clogged increased. In addition to decreases in discharge for emitters that were clogged, the model showed an increase of pressure at the manifold inlet. Due to the increased inlet pressure, a lower discharge rate by the pump wasobserved.

Berkowitz [15] observed reductions in emitter irri- ga- tion flow ranging from 7 to 23% at five sites observed. Reductions in scouring velocities were also observed from the designed 0.6 m/s (2ft/s) to 0.3 m/s (1ft/s). Lines also developed some slime build-up, as reflected by the reduction in scouring velocities, but this occurred to a less degree with higher quality effluent.

In their treatments they generally used approximate friction equations such as Hazen-Williams and Scobey, neglected the variation of the velocity head along the lateral and assumed initial uniform emitter flow. War- rick and Yitayew[16] assumed a lateral with a lon- gitu- dinal slot and presented design charts based on spa-tially varied flow. The latter solution has neglected the presence of laminar flow in a considerable length of the downstream part of the lateral. Hathoot*et al.* [17] pro- vided a solution based on uniform emitter discharge but took into account the change of velocity

head and the variation of Reynold'snumber. They used the Darcy-Weisbachfriction equation in estimating friction losses. Hathoo*et al.* [18] considered individual emitters with variable outflow and presented a step by step computer program for designing either the diameter or the lateral length. In this study we considered the pressure head losses due to emitters protrusion. These losses occur when the emitter barb protrusion obstructs the water flow. Three sizes of emitter barbs were specified, small, medium and large in which the small barb has an area equal or less than 20 mm^2, the medium barb has an area between 21-31 mm^2 and the large one has an area equal to or more than 32 mm^2 Watters *et al.*[19]. The objectives of the present research were:Investigate emitter discharge application uniformity and its dependence on operation pressures and Laterals lengths (40, 60, and 80m).To compare water and energy use efficiencies be- tween Tow type of closed circuits (COMDIS and CTMDIS) relative to Traditional Drip System(TDIS).

2. MATERIALS andMETHODS

2.1.Site Location and ExperimentsDesign

This experiment was conducted at Irrigation Devices and Equipments Tests Laboratory, Agricultural Engineering Research Institute, Agriculture Research Center,. A. Mansour *et al.* / Agricultural Sciences 2(2010)154-177157

Cairo, Egypt, The experimental design was randomized complete block with three replicates. Three irrigation Lateral Lines 40, 60, 80 m long that were installed at constant level and under Ten operating pressures 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, and 2.0 bar for Ten min-utes at each pressure. Details of the pressure and water supply control have been described by (Safi *et al.*, 2007), to evaluate the Built-in Dripper (GR), discharge, 4 lph design emitter spacing of 30 cm at 1 bar nominal oper- ating pressure in order to reach an modified way to re- solve the problem of lack of pressure at the end of lateral lines in the traditional drip irrigation system.

2.2. Field ExperimentalSite

This field experiment was conducted at the Experi- mental Farm of Faculty of Agriculture Southern Illinois University at Carbondale (SIUC). District (latitude 37º.73 N, altitude 89º.16 W, Height about 118 m/387feet
above sea level), Illinois, USA.

2.3. Drip SystemComponents

The components of closed circuits the drip system in- clude, supply lines, control valves, supply and return manifolds, drip lateral lines, drip emitters, check valves and air relief valves/ vacuum breakers. **Figures 2**, **3** show the closed circuits of drip irrigation system: 1) Closed circuit with Tow Manifold of Drip Irrigation System (CTMDIS) and 2) Closed circuit with One Manifold of Drip Irrigation System (COMDIS) while **Figure 4** is **Figure 3**. Traditional of Drip Irrigation System (TDIS). Supply lines provide water to the supply manifolds of the system after passing through the zone control valve in systems with more than one zone. The supply mani- fold distributes water to the individual drip laterals within the zone. The laterals then connect to a return manifold. Along the supply and return manifold,air relief/vacuum breakers are installed at the highest point of the manifolds to allow air to enter the system during depressurization (Netafim, 2002).

The return manifold is used during system flushing to collect water from the laterals and carry it to the return line which returns to the pretreatment device. Prior to connecting the return manifold to the return line a check valve is installed to prevent water from entering the zone during the operation of other zones.

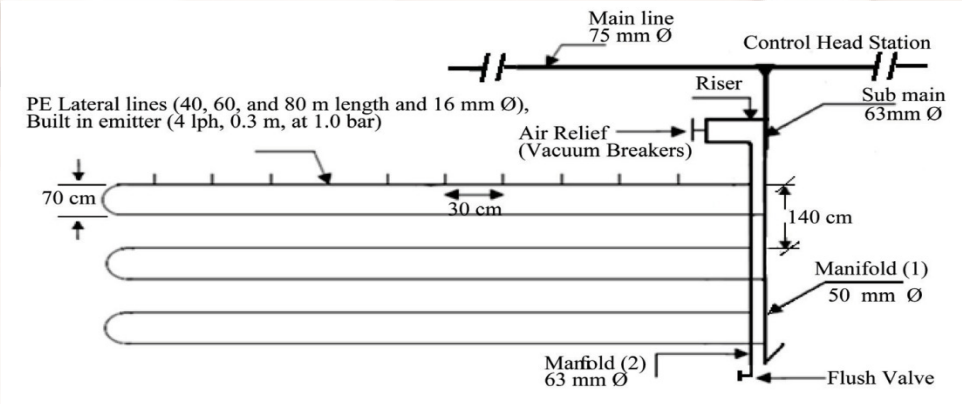

Figure 2. Layout of closed circuit with tow manifolds of drip irrigation system (CM2DIS).

Figure 3. Layout of closed circuits with one manifold of drip irrigation system (CM1DIS).

2.4. Head Loss in aPipe

The flow in the pipe throughput depends on pipe sur- face roughness and air layer resistance. The change of hydraulic friction coefficient values, depending on varia- tions in Re number values. Hydraulic losses at plastic pipes might be calculated as losses at hydraulically smooth pipes, multiplied by correction coefficients that assess losses at pipe joints and air resistance.

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Measurements of Maize (Zea Mays L.) Yield

Plantmeasurements:

where v = fluid velocity, m/sec; D = Internal pipe dia- meter of lateral, m; and v = kinematic viscosity of water
$= 1 \times 10^{-6}$ m²/sec, at 20⁰C. Velocity v can be expressed as:

Components of yield were that measured grain weight Kg/ha.

$v = Q / A$

Water use efficiency:

Water use efficiency is an indicator of effectiveness use of irrigation unit for increasing crop yield. Water use efficiency of seed yield was calculated from **Eq.1**

2.6. Calculating EnergyRequirement

The amount of energy needed to pump water depends on the volume of water to be pumped and the head re- quired and can be calculated using the formula:

Water energy (kWh) = volume of water (m^3) × head(m)/367 (8)

Increasing either the volume of water or the head will directly increase the energy required for pumping.

Energy use efficiency [5]

Water energy (kWh) = water power (kW) ×operating-time(h) (9)

Pumpingplantefficiency(%)=(waterenergy/actualenergy)×100 (10)

Power use efficiency [5]

Waterpower(kW)=9.81×discharge(m^3/s)×head (m) (11)

Pumping plant power efficiency (%) = (waterpower/ power input) × 100(12)

Head loss due to friction

The head loss due to friction was calculated using the Darcy-Weisbach equation:

where, Q = lateral flow rate (average flow rate per emit- ter × number of emitters), and A = cross sectional area of lateral.

The calculated emission rates were then compared with the measured values to see the differences between them.

2.7. Using Computer Program for HydraulicCalculations

HydroCalc irrigation system planning software is de- signed to help the user to define the parameters of an irrigation system. The user will be able to run the pro- gram with any suitable parameters, review the output, and change input data in order to match it to the appro- priate irrigation system set up. Some parameters may be selected from a system list; whereas other are entered by the user according to their own needs so they do not conflict with the program's limitations. The software package includes an opening main window, five calcula-

tion programs, one language setting window and a data- base that can be modified and updated by the user.

HydroCalc includes several sub-programs as:

The Emitters program calculates the cumulative pres- sure loss, the average flow rate, the water flow velocity etc. in the selected emitter. It can be changed to suit the desired irrigation system parameters.

The SubMain program calculates the cumulative pressure loss and the water flow velocity in the submain distributing water pipe (single or telescopic). It changes to suit the required irrigation system parameters.

$$h=f(L/D)\times(v^2/2g)$$

The Main Pipe program calculates the cumulative

$$\text{WUE of seed yield (ton /m}^3\text{)}=\frac{\text{Totalseedyield (ton/fed.)}}{\text{Total applied irrigation water m / fed.}}$$

pressure loss and the water flow velocity in the main conducting water pipe (single or telescopic). It changes to suit the required irrigation systemparameters.

The Shape Wizard program helps transfer the re- quired system parameters (Inlet Lateral Flow Rate, Minimum Head Pressure) from the Emitters program to the SubMain program.

The Valves program calculates the valve friction loss according to the given parameters.

The Shifts program calculates the irrigation rate and number of shifts needed according to the given parame- ters.

The Emitters program is the first application which can be used in the frame of HydroCalc software program. There are 4 basic type of emitters which can be used: Drip Line, on line, Sprinklers and Micro-Sprinklers. According to the previous selection the user can opt for a specific emitter which can be a pressure compensated or a non pressurecompensated.

Each emitter has its own set of nominal flow rate val- ues available. After the previous mentioned fields were completed, the program automatically fills the following fields: “Inside Diameter”, “KD” and “Exponent”, values which cannot be

changes unless the change will be made in the database. The segment length is next field in which the user must introduce a value. The end pressure represents the actual value for calculation of pressure at the furthest emitter. There are some common values for this field: around 10 m for drippers, around 20 m for mini-sprinklers, between 20 – 30 m for sprinklers and around 2 m when using the flushing system. There are 2 more options which can be filled before starting the computation, options which can also be used with their default values. The Flushing field can be used if the user intends to calculate a system that includes and lateral flushing. Flushing option will work only insubsequently
will be used the "Emitter Line Length" calculation method. The second option is about topography. Default value is 0%. Topography field has 2 sub-fields: fixed slope and changing slope. Usually the slopes values are not exceeding 10%. In many cases the slope is not uni- form.

3. VALIDATION of MEASURED DATA WITH CALCULATED DATA BY HYDROCALC

The emission rate for 10 emitters tested for each Lat- eral line for lengths (40, 60 and 80 m) at three stages First, middle and end on the line were calculated theo- retically using the following procedure.

The head loss due to friction and insertion of emitters was calculated and then the pressure head at every emit- ter was determined. The emission from every emitter was calculated using the characteristic equation devel- oped for pressure head vs. discharge for eachproduct.

3.1. Field Experiments

Field experiments were carried out through one suc- cessive growing season (2009/2010) under three closed circuits of drip irrigation systems, 1) One manifold for lateral lines or Closed circuits with One Manifold of Drip Irrigation System (CM1DIS); 2) Closed circuits with Two Manifolds of Drip Irrigation System (CM2DIS), and 3) Traditional Drip Irrigation System (TDIS) as a

control. Lateral lines length were 40, 60 and 80 meters. PE tubes lateral lines: 16 mm diameter; 30 cm space drippers, and GR built-in drippers 4 lph for length unit when operating pressure 1 bar. Soil of ex- perimental field represents the silty clay loam plots area has been showed in **Figure7**.

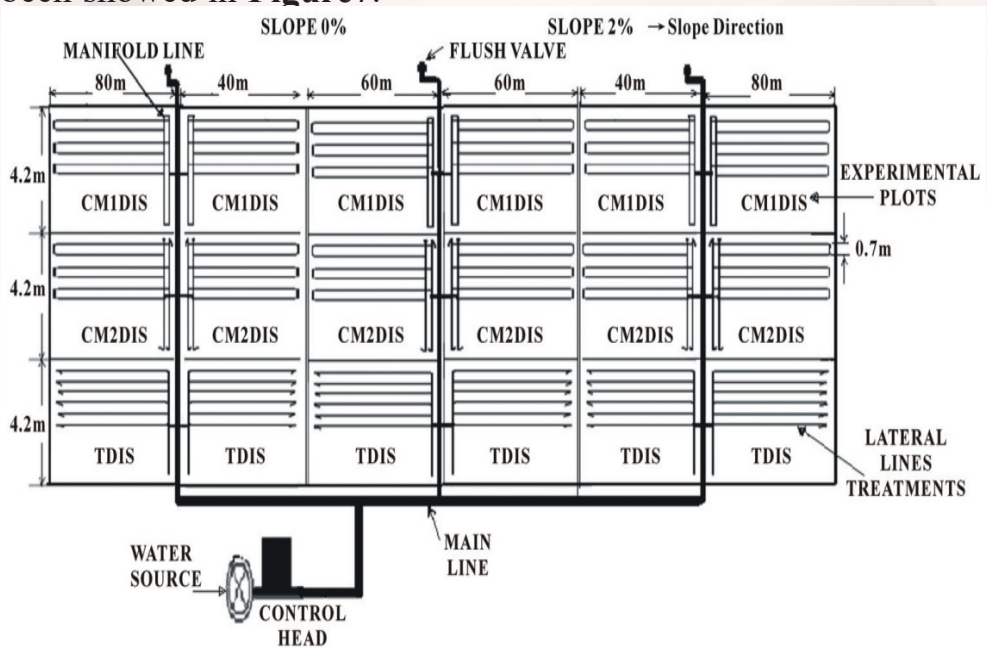


Figure 7. Layout of the experimental plots: Treatment L = 40 m; L = 60 m and L = 80 m different Field conditions Slope 0%; Slope 2% levels.

3.2.SoilCharacteristics

Soil particle size distribution was carried out using pipette method after Gee and Bauder (20) as shown in **Table 1**.

Soil pH and EC were measured in 1:2.5 soil water suspensions and in soil past extract, respectively accord- ing to Jackson (21) as show in **Table 2**.

Irrigation water analysis:

Ground water is the source of irrigation water. Irriga- tion water analysis is given in **Table 3**.

3.3.Description ofInstallation

The project was carried out during the irrigation sea- son of

the year 2009/2010 on the farm of the Experi- mental Farm of Faculty of Agriculture Southern Illinois University at Carbondale (SIUC) **Figures 4-6**. A drip irrigation system was installed on the plots and here the effect of Connection methods of closed circuits (CM1DIS; CM2DIS) and different Lateral Lengths (40, 60 and 80 m) on the maize yield was studied and evalu- ated.

3.4. Statistical Analysis

All the collected data were subjected to the statistical analysis as the usual technique of analysis of variance (ANOVA) and the least significant difference (L.S.D) between systems at 1% had been done. The random- ized complete block design according to **Dospekhov (1984)**.

4. RESULTS AND DISCUSSIONS

4.1. Effect of Different Operating Pressures on Drippers Change of Discharges on Lateral Lines when Slope0%.

In **Table 4** and **Figures 8-10** we can be observed there was a direct relationship between the operating pressures and the average discharge of lateral lines along the lines in all cases and this is logical. When operating pressure
0.8 bar was under used CM2DIS method, the average of discharge when lateral length 40 m was 4.48 Lph and when using the CM1DIS and the value of the average

Table 1. Some p hysical properties of Carbondale site.

cm	C. Sand	F. Sand	Silt	Clay	F.C., %	W.P., %	AW	class
0-15	3.4	29.6	39.5	27.5	32.35	17.81	14.44	S.C.L
15-30	3.6	29.7	39.3	27.4	33.51	18.53	14.98	S.C.L
30-45	3.5	28.5	38.8	28.2	32.52	17.96	14.56	S.C.L
45-60	3.8	28.7	39.6	27.9	32.28	18.61	13.67	S.C.L

S.C.L.: Silty ClayLoam

Table 3. Some chemical data of irrigation water at Carbondale site

0-15	7.3	0.35	0.50	0.49	0.52	0.22	0.00	0.58	0.30	0.38
15-30	7.2	0.36	0.51	0.50	0.48	0.24	0.00	0.68	0.41	0.49
30-45	7.3	0.34	0.63	0.54	0.46	0.23	0.00	0.79	0.43	0.63
45-60	7.4	0.73	0.67	0.58	0.44	0.21	0.00	0.87	0.44	0.74

Table 4. Comparison between ReggritionCooeficients R^2 among

Irrigation manifold connec-	**R^2 Value when Lateral Length(m)**		
tions Method	**40**	**60**	**80**
CM2DIS	0.9712	0.9506	0.9397
CM1DIS	0.9693	0.9414	0.9368
TDIS	0.9565	0.9354	0.9153

the pessures and discharges values when slope 0%.
discharge was 4.20 Lph under the same length of the line.

While with the change in the operating pressure where it's increased to 1.0 bar. When the length of lateral lines was 40m, the average value of the discharge in this case was 4.48 Lph under using CM2DIS While the average value of the discharge was 4.33 Lph with using the method CM1DIS.The lateral lines at all cases of Control TDIS and lengths 60 and 80 m under used (CM2DIS, CM1DIS), the average value of the discharge didn't reach the standard value for this type of drippers (GR Built-in) where the standard value for this type of drip- pers is 4 Lph at the operating pressure is 1.0 bar as showing below the **Table 4** and **Figures 8-10**.

Data in **Table 4** and **Figures 8-10** show the rela- tionship between different pressures (bar) and the dis- charge (Lph) for the closed circuits different connection methods, CM2DIS and CM1DIS with used different lateral length 40 m the discharge be arrived to the stan- dard value of this dripper type when the pressure value was 0.8 bar. While with used lateral length 60 m under CM2DIS, the discharge be arrived to the standard value when the pressure value was 1.2 bar. By compared with TDIS when the same conditions we didn't arrived to the standard

discharge at the three lateral lengths 40, 60 and 80 m absolutely.

According to the Regression coefficient R^2 as show in **Table 4** and **Figures 8-10**, we can note that when used the closed circuits CM2DIS the values of R^2 were 0.971, 0.950 and 0.939 with Lateral lengths 40, 60 and 80 m
respectively. Under used CM1DIS R^2 values were 0.969, 0.941 and 0.936 with lateral lengths 40, 60, and 80 m, respectively. While under used the traditional drip sys- tem TDIS R^2 values were (0.956, 0.935, and 0.915) with lateral lengths 40, 60 and 80 m, respectively. This mean that the best regression between the different pressures and discharges when used lateral length 40 m under CM2DIS and CM1DIS.

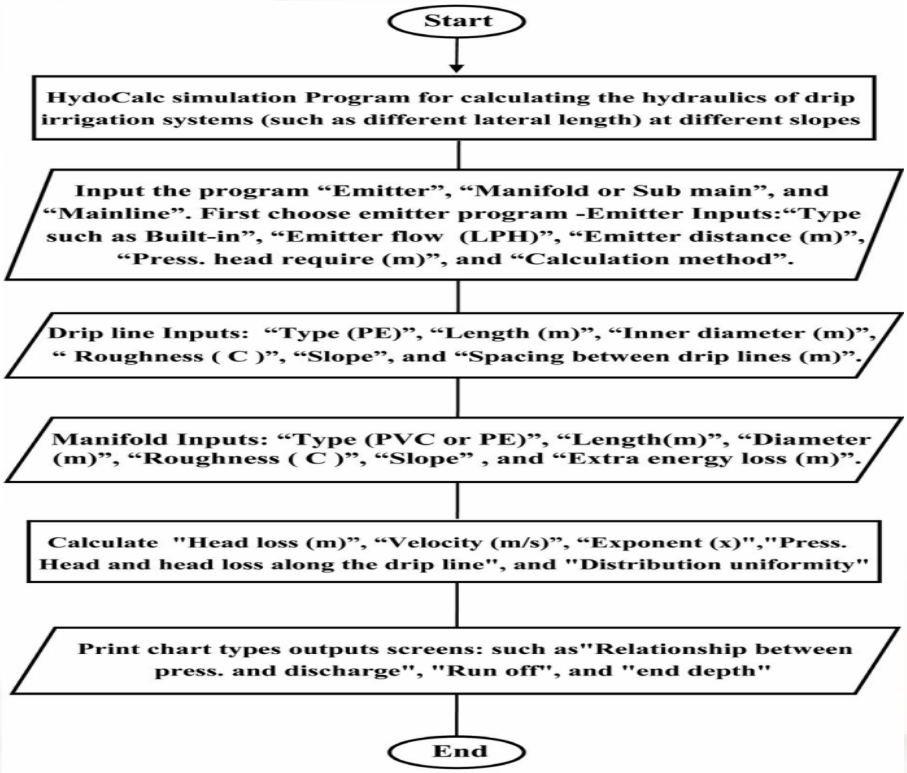
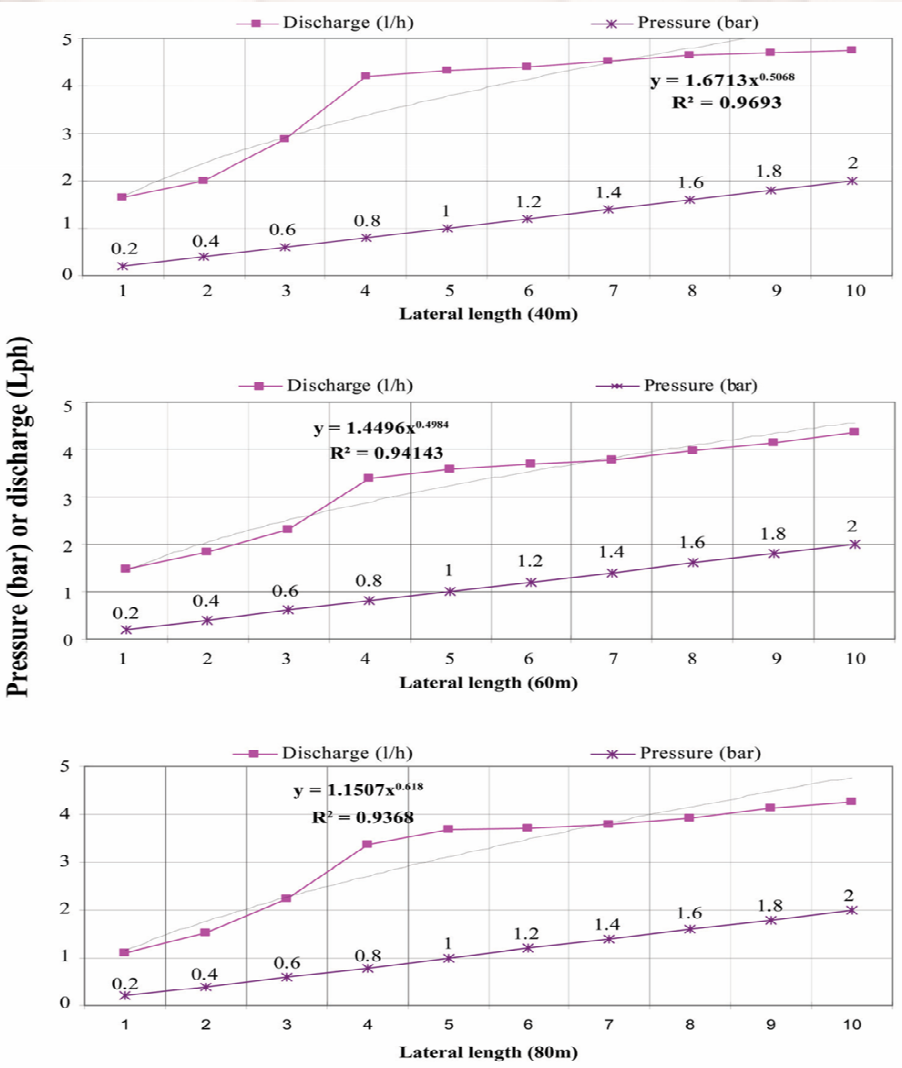


Figure 6. Flow chart components of HydroCalc simulation program for planning, design, and calculating the hydraulic analysis of drip irrigation system at different slopes or levels.

The Selected Drippers on the lateral lines of (CM2DIS)

Figure 8. Effect of different operating pressures (bar) on



discharges of the closed circuits connections (CM2DIS) type when slope 0%.

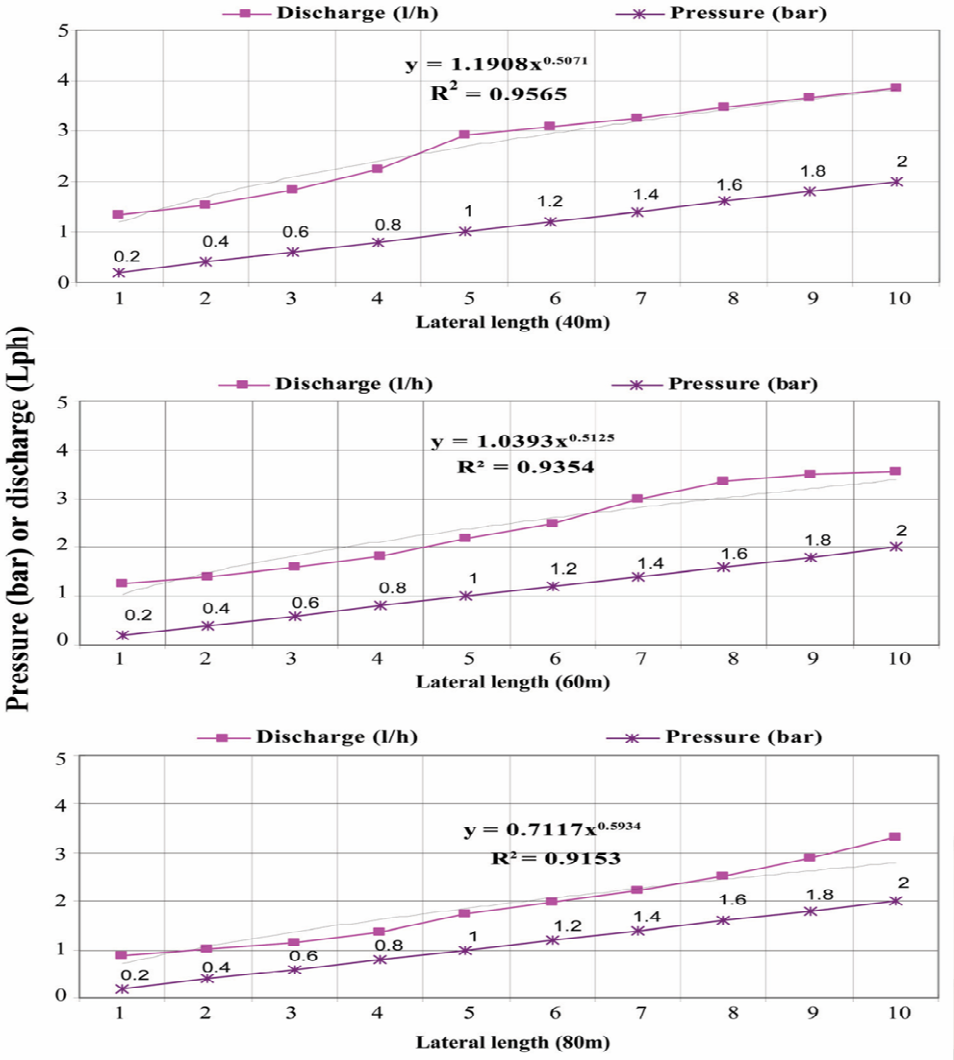
4.2. Effect of Different Operating Pressures on Drippers Discharge on Lateral Lines when Slope2%

In **Table 5** and **Figures 11-13** we can be observed there was a

direct relationship between the operating pressures and the average discharge of lateral lines along the lines in all cases and this is logical. When operating pressure 0.8 bar was under used CM2DIS method, the average of discharge when lateral length 40 m was 4.46

The Selected Drippers on the lateral lines of (CM1DIS)

Figure 9. Effect of different operating pressures (bar) on discharges of the closed circuits connections (cm1dis) type when slope0%.

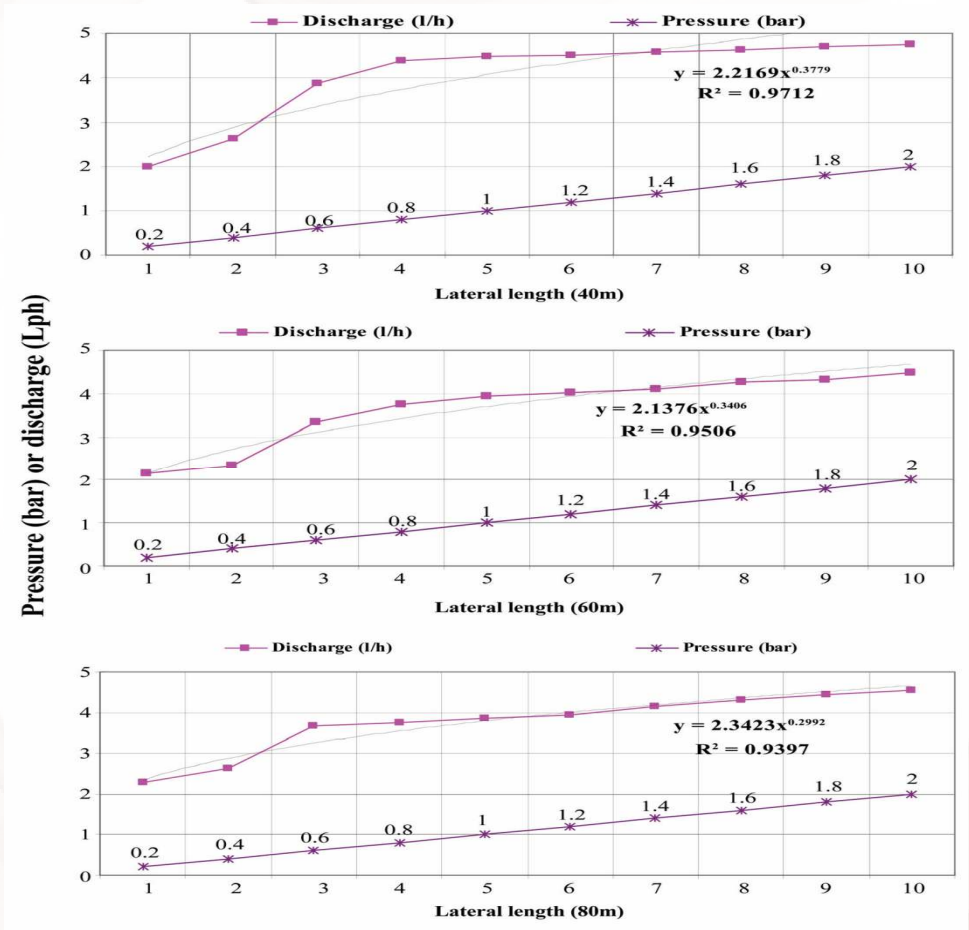


Lph and when using the CM1DIS and the value of the average discharge was 4.32 Lph under the same lateral line length.

While with the change in the operating pressure where it's increased to 1.0 bar. When the length of lateral lines was 40m, the average value of the discharge in this case was 4.56 Lph under using CM2DIS While the average value of the discharge was 4.45 Lph with using the method CM1DIS.The lateral lines at all cases of Control TDIS and lengths 60 and 80 m under used (CM2DIS, CM1DIS), the average value of the discharge didn't reach the standard value for this type of drippers.

The Selected Drippers on the lateral lines of (TDIS)

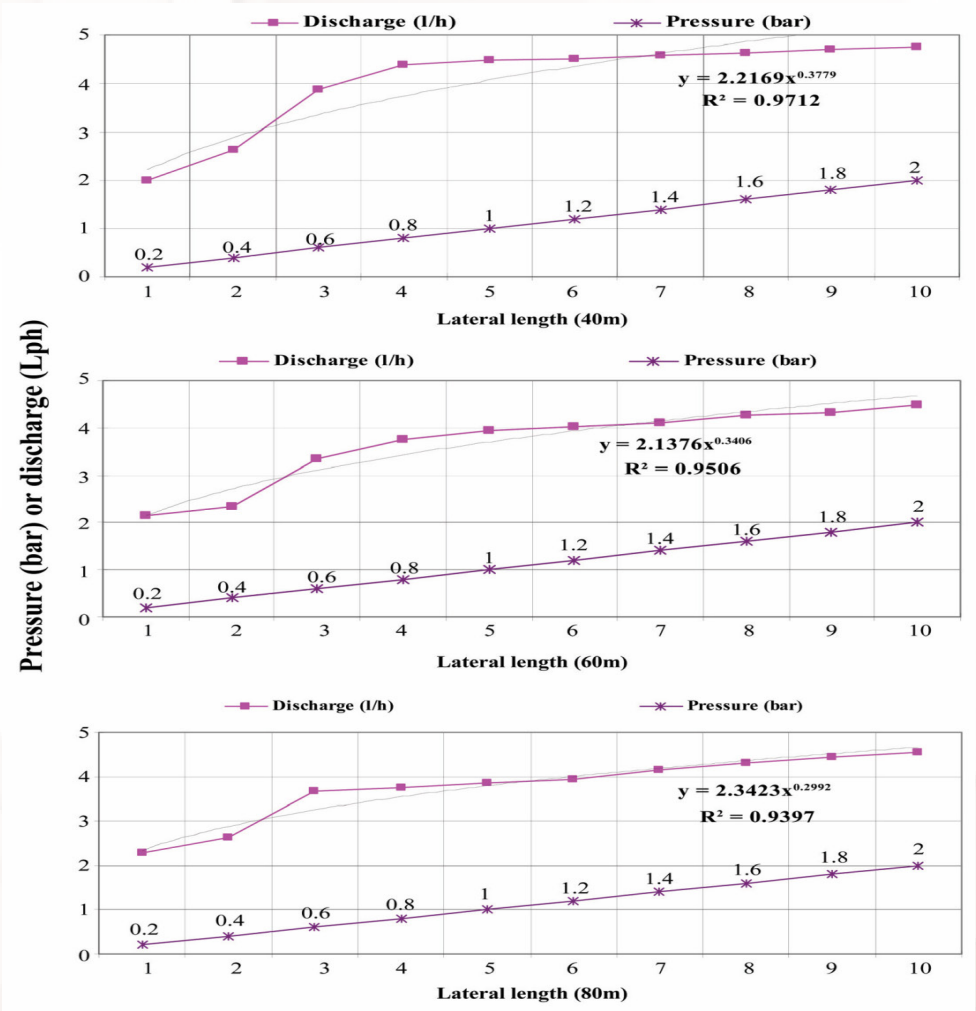
Figure 10. Effect of different operating pressures (bar) on



discharges of the traditional drip system (TDIS) when slope 0%.

Table 5. Comparison between ReggritionCooeficients R^2 among the pessures and discharges values when slope 2%.

Irrigation manifold connections Method	R^2 Value when Lateral Length (m)		
	40	60	80
CM2DIS	0.9756	0.9618	0.9531
CM1DIS	0.9713	0.9463	0.9251
TDIS	0.9625	0.9552	0.9314



The Selected Drippers on the lateral lines of (CM2DIS)

Figure 11. Effect of different operating pressures (bar) on discharges of the closed circuits connections (CM2DIS) type when slope 2 %.

Built-in) where the standard value for this type of drip- pers is 4 Lph at the operating pressure is 1.0 bar as showing below the **Table 5** and **Figures 11-13**.

Data in **Table 5** and **Figures 11-13** show the rela- tionship between different pressures (bar) and the dis- charge (Lph) for the closed circuits different connection methods, CM2DIS and CM1DIS with used different

lateral length 40 m the discharge be arrived to the stan- dard value of this dripper type when the pressure value was 0.8 bar. While with used lateral length 60 m under CM2DIS, the discharge be arrived to the standard value when the pressure value was 1.2 bar. By compared with TDIS when the same conditions we didn't arrived to the standard discharge at the three lateral lengths 40, 60 and

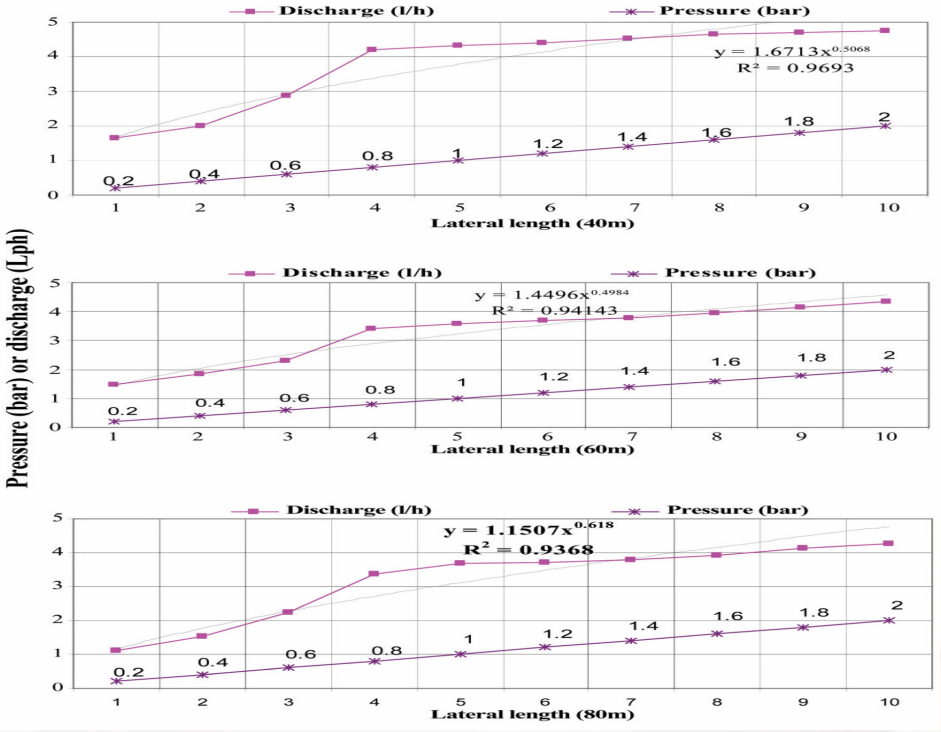
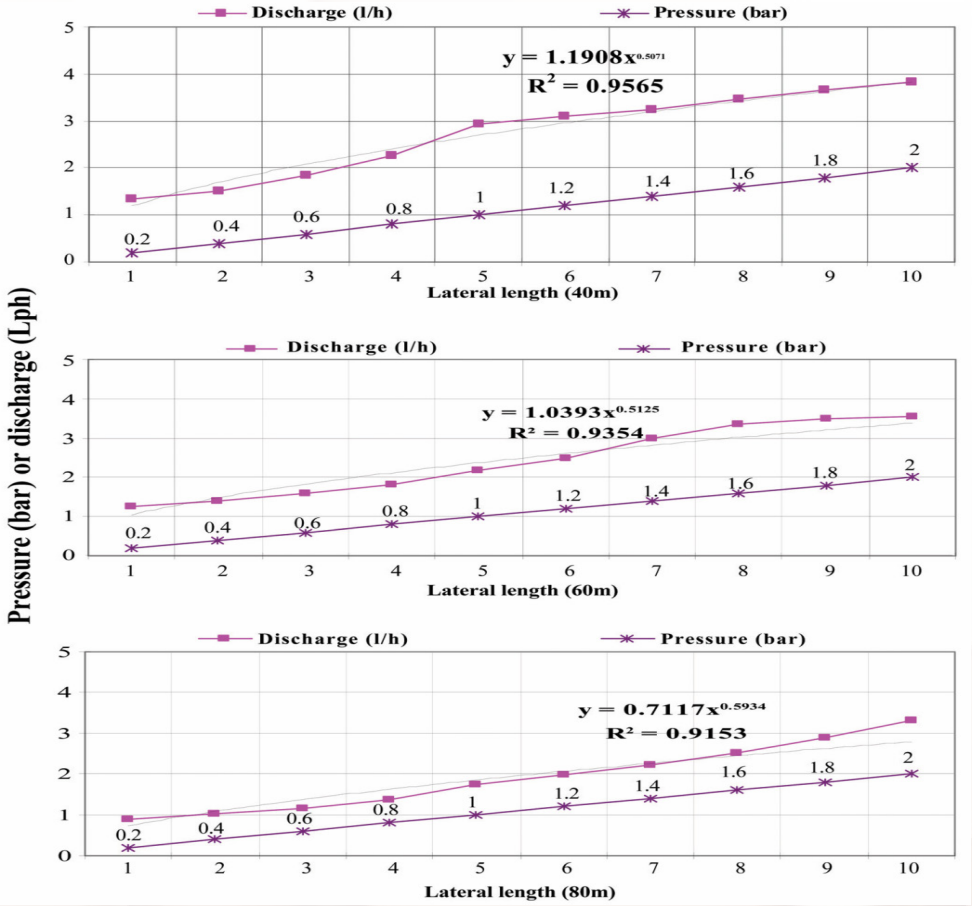


Figure 12. Effect of different operating pressures (bar) on Discharges of the closed circuits connec- tions (CM1DIS) type when slope 2%.

According to the Regression coefficient R^2 as show in **Table 5** and **Figures 11-3**, we can note that when used the closed circuits CM2DIS the values of R^2 were 0.9756, 0.9618 and 0.9531 with Lateral lengths 40 , 60 and 80 m respectively. Under used CM1DIS R^2 values were 0.9713, 0.9463 and 0.9251 with lateral lengths 40, 60,and80m,respectively.Whileunderusedthetradi-tional drip system TDIS R^2 values were (0.9625, 0.9552, and 0.9314) with lateral lengths 40, 60 and 80 m, respec- tively. This mean that the best regression between the different pressures and discharges when used lateral length 40 m under CM2DIS and CM1DIS.

We can note also the pressure value of effective more (PVEM) when slope 0 and 2%, its value which make large increase in the discharge and after this value.



The Selected Drippers on the lateral lines of (CM2DIS) discharge can't decrease, Absolutely. When used CM2DIS connection method at all lateral lengths 40, 60, and 80 m the PVEM was 0.6 bar, and under CM1DIS, with all lateral lengths treatments 40, 60, and 80 m the PVEM was 0.8 bar, while the traditional drip method at all lat- eral lengths 40, 60, and 80 m the PVEM was 1.0 bar.

5. VALIDATION of LATERAL LINES HYDRAULIC ANALYSIS by HYDROCALC SIMULATION PROGRAM WHEN SLOPE 0% AND 2%

5.1. Validation of HydrocalcSimulation Program

The discharges and pressures head at three sites along the laterals drip line (Start, Middle and End) closed cir- cuit connection drip irrigation systems [closed circuit with tow separates manifold lines (CM2DIS), closed circuit with one manifold line (CM1DIS), and the tradi- tional drip system (TDIS) as a control] with different lateral lengths (40, 60, and 80 m) were measured under field conditions for two different slopes of the drip line (0 and 0.2%) to validate the drip simulation program (HydroCalc Simulation program copyright 2009 devel- oped by NETAFIM, USA), which is a computer simula- tion Program for planning and design of drip or sprinkler irrigation systems as used for Modification of closed circuit drip lateral lines irrigation, depends on the hy- draulic equations such as, Hazen-William's Eq., Per- nolli's Eq., etc. The inputs were illustrated in **Table6**.

Data show in **Table 6**, are the inputs of HydroCalc simulation program to simulate closed circuit of drip irrigation systems under field conditions with two slopes 0% and 2% of HydroCalc simulation progrm under (CM2DIS, CM1DIS, TDIS)). The predicted outputs of HydroCalc simulation program (Exponent (X), pressure head loss (m), Velocity (m/s), and pressure analysis along the drippers lateral line) **Figures 14-16** depend on the field measurements of pressures and discharge, as well as the predicted the field distributionuniformity.

5.2. Predicted and Measured Head Loss Analysis along the Lateral Dripper Line of Closed Circuits under 0% Slope

The predicted head loss analysis along the lateral drippers line had been calculated by HydroCalcsimula- tion program for closed circuits drip irrigation systems
CM2DIS and CM1DIS compared with TDIS when slope 0% with different Lateral lengths 40, 60, and 80 m.

Figures 14-16 and **Table 7** show the relationship be- tween predicted and measured head losses as well as regressions and correlations Under CM2DIS, CM1DIS, and TDIS methods when slope 0% level. It is obvious that the irrigation methods under study when using Lat- eral Length 40 m could be arranged in the following ascending order according the values of the predicted and measured head losses CM2DIS < CM1DIS <TDIS.

According to the Lateral Length 60 m. the irrigation methods could put in the following ascending orders CM1DIS < CM2DIS < TDIS. While by using Lateral length 80m the values of the predicted and measured head losses under irrigation methods could be arranged in the following ascending orders CM2DIS < CM1DIS < TDIS. This may be attributed to the different of numbers or how many dripper built-in with every lateral line length.

5.3. Predicted and Measured Head Loss Analysis along the Lateral Dripper Line of Closed Circuits under 2% Slope

The predicted head loss analysis when slope 2% along the lateral drippers line direction had been calculated by HydroCalc simulation program for closed circuits drip

Table 6. Inputs of hydrocalc simulation program for closed circuits drip irrigation systems.

Manifold		Drip line		Emitters	
Name	**Value**	**Name**	**Value**	**Name**	**Value**
Pipe type:	PVC	**Tubes type**	PE	**Emitter type**	Built in
Pipe length:	-----	**Tubes lengths:**	40, 60, and 80 m	**Emitter Flow (Lph)**	4.0
Pipe diameter:	0.05 m	**Inner diameter**	0.0142 m	**Emitters distance**	0.30 m
(C) Pipe Roughness:	150	**(C) Pipe Roughness**	150	**Press Head Require (m)**	10.0 m
Slope:	0 m/m	**Slope**	0 or 0.02 m/m	**Calculation Method**	Flow Rate Variation
Extra energy losses:	0.064	**Spacing**	0.7 m	---	---

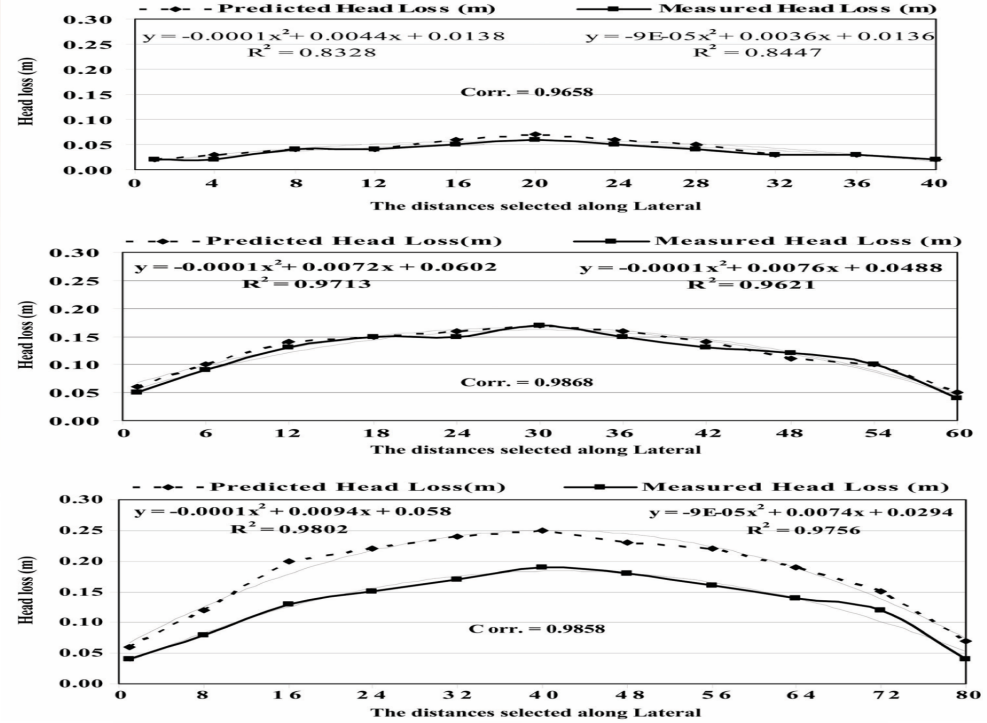
Table 7. Outputs Predicted of hydraulic analysis by hydrocalc simulation program for closed circuits drip irrigation systems with different slopes 0 and 2%.

Field

slope, (%)	length, (m)	CM2DIS			CM1DIS			TDIS		
		Expo-nent (x)	Headloss (m)	Velocity (m/s)	Expo-nent (x)	Head loss (m)	Velocity (m/s)	Exponent (x)	Head loss (m)	Velocity (m/s)
0	40	0.72	0.64	1.58	0.69	0.73	1.55	0.58	1.43	1.52
	60	0.65	1.48	1.63	0.61	1.55	1.57	0.55	2.35	1.64
	80	0.58	3.00	1.92	0.52	3.11	1.88	0.53	3.58	2.18
2	40	0.76	0.45	1.51	0.71	0.76	1.51	0.63	1.38	1.51
	60	0.68	1.34	1.57	0.64	1.55	1.55	0.59	2.26	1.62
	80	0.61	2.92	1.89	0.58	3.00	1.74	0.55	3.37	1.97

WATER USE EFFICIENCY(WUE)

Data in **Tables 9**, **10** show that, Water Use Efficiency (WUE) when level slope 0% under CM2DIS were 1.67, 1.18, and 0.87 kg/m^3 compared to 1.65, 1.16, and 0.86



kg/m^3 with CM1DIS and 1.35, 1.04, and 0.75 kg/m^3 with TDIS whereas with level slope 2% when using CM2DIS were 1.76, 1.29, and 0.84 kg/m^3 compared to 1.77, 1.30,
and 0.87 kg/m^3 with CM1DIS and 1.41, 1.12, and 0.76 kg/m^3 (for lateral lengths 40, 60, and 80 meters respec- tively).

6. CONCLUSIONS

It could be concluded that:

The pressure value of effective more when slope 0% and 2% (PVEM) it's value which make large increase in the discharge and after this value the discharge can't decrease, Absolutely. When used CM2DIS connection method at all lateral lengths 40, 60, and 80 m the PVEM was 0.6 bar, and under CM1DIS, with all lateral lengths treatments 40, 60, and 80 m the PVEM was 0.8 bar, while

the traditional drip method at all lateral lengths 40, 60, and 80 m the PVEM was 1.0bar.

Irrigation systems at 40, 60, 80 m could be arranged according to Energy Use Efficiency (EUE), Water Use Efficiency (WUE), in the following ascending order: TDIS < CM1DIS < CM2DIS. Irrigation systems at 40, 60, 80 m could be arranged according to friction losses of lateral lines in the following ascending order: CM2DIS < CM1DIS <TDIS.

Under 0% level slope in when using CM2DIS the in- creases percentage of Energy Use Efficiency (EUE) were 32.27, 33.21, and 34.37 % while withCM1DISwere 30.84, 28.96, and 27.45 % whereas under slope 2% were with CM2DIS 31.57, 33.14, and 34.25 on the other hand CM1DIS were 30.15, 28.98, and 27.53 under lat- eral lengths 40, 60 and 80 m respectively relative to TDIS.

Water Use Efficiency (WUE) when level slope 0% under CM2DIS were 1.67, 1.18, and 0.87 kg/m^3 com- pared to 1.65, 1.16, and 0.86 kg/m^3 with CM1DIS and 1.35, 1.04, and 0.75 kg/m^3 with TDIS whereas with level slope 2% when using CM2DIS were 1.76, 1.29,and 0.84 kg/m^3 compared to 1.77, 1.30, and 0.87 kg/m^3 with CM1DIS and 1.41, 1.12, and 0.76 kg/m^3 (for lateral lengths 40, 60, and 80 meters respectively).

Percentage of water saving varied widely within indi- vidual lateral lengths and between circuit types relative to TDIS. Under slope 0% level CM2DIS water saving percent values were 19.26, 12.48, and 14.03%; with CM1DIS they were 18.51, 10.50, and 12.78%; andunder slope level 2% with CM2DIS they were 19.93, 13.26, and10.38%andCM1DISwere20.49,13.96,and13.23 % (for lateral lengths 40, 60, 80 meters respectively).

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