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IMPROVING EMITTER OUTFLOW UNIFORMITY WITHIN A DRIP IRRIGATION SUBUNIT

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ABSTRACT

Comparison between traditional end-closed drip irrigation laterals, connected laterals at their ends using a second downstream manifold, and closed circuits looped laterals is performed to analyze the hydraulics of the distribution systems and to assess outflow uniformity. Detailed solutions for the three alternatives are achieved using the Engineering Equation Solver (EES). This software can solve a set of nonlinear equations simultaneously. A drip irrigation subunit of 250 m x 60 m is analyzed using EES to determine emitters' pressures and discharges for 66 runs. Some runs cover emitter characteristics, pumping heads, manifold slopes, lateral slopes, diameters of the second downstream manifold, and other runs cover the case when few laterals are closed at their inlets. Christiansen uniformity coefficient and the relative flow difference are calculated for all cases to compare the distribution uniformity of the three alternatives. The results show that connected laterals generally achieve higher uniformity except in very few cases related to the land topography. The looped lateral alternative is equivalent to the traditional end-closed alternative giving the same coefficient of flow uniformity.

KEYWORDS: flow uniformity; drip irrigation; lateral-manifold hydraulics.

1. INTRODUCTION

Drip irrigation technology is to water plants frequently and with small volumes of water approaching the plants consumptive use. Many advantages are achieved by this technology as it minimizes runoff, deep percolation and evaporation from the soil surface [1]. Hence, the water use efficiency is increased. In addition; drip irrigation maximizes the flexibility in fertilization and other chemical application scheduling. Drip irrigation can save energy as the operating pressure is usually lower than other

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types of pressurized systems. However, most of the energy conservation should come from reducing the quantity of the water pumped. Due to the clear merits of drip irrigation, within the last two decades; the area irrigated using drip and other micro-irrigation methods has increased by 6.4 folds; from 1.6 million hectares to over 10.3 million hectares [2].

The design engineer of drip irrigation systems should aim to achieve high water distribution uniformity. The design can be made to achieve a completely uniform emitter flow by using different emitter sizes or by using pressure compensating emitters. In general practice, the emitter characteristics are usually fixed, and the emitter flow rate is determined by pressure head at the emitter in the line. There is pressure variation within the subunit due to pipe friction and land topography. To reduce friction losses to minimize pressure head variation within a subunit, the diameter of both the manifold and lateral pipes should be increased (relaxed sizing). Economics dictates how large these diameters should be.

For quantitative evaluation of the emitter flow variation, one can use Christiansen Uniformity Coefficient (1942) for sprinkler irrigation.

$$C_u = 1 - \frac{\sum_{i=1}^{i=n} |q_i - \bar{q}|}{n\bar{q}} \quad (1)$$

Where C_u is Christiansen uniformity coefficient, $\bar{q}$ is the mean emitter flow, $\overline{\Delta q}$ is the absolute mean deviation from the mean emitter flow, q_i is the outflow from an individual emitter (i) and n is the number of emitters in the subunit.

There are other ways of expressing the emitter flow variation by simply comparing the maximum q_{max} and the minimum q_{min} emitter flows within the subunit [3].

$$q_{var} = \frac{q_{max} - q_{min}}{\bar{q}} \quad (2)$$

The main objective of this article is to study the impact of modifying the traditional closed end laterals to connected laterals at their ends by introducing a second downstream manifold or by looping the laterals to end at the upstream main manifold. The second alternative of connected laterals is expected to improve the uniformity as it serves to equalize pressure between driplines during normal operation. The second downstream manifold can also be used in subunit flushing.

The maximum lateral length corresponding to a certain value of uniformity coefficient was calculated [4]. The solution depends on pipe size, pipe roughness coefficient, elevation change, the average emitter flow rate, the emitter flow function, reduction coefficient for dividing flow, and the number of emitters per lateral. Dimensionless charts were proposed which can be used in the design of trickle irrigation laterals.

A study for the design of drip irrigation lateral line was made [5]. Complete derivation of the inflow-outflow and the double-inlet systems were proposed. Moreover, design charts for both systems were developed.

A computer model to analyze lateral line of drip irrigation system by predicting emitter discharge uniformity was developed [6]. This uniformity was defined by a coefficient of variation that is a combination of variation due to hydraulics and statistical variation due to manufacturing. The pressure-discharge relationships and the coefficient of manufacturer's variations for 14 commercial emitters were determined for model validation and utilization.

Direct equations to design a drip irrigation system using computer was developed [7]. Emitter flows along a submain and lateral line can be calculated directly based on an energy gradient line approach. Errors caused by this approach can be evaluated by a computer simulation. Hence, the design of drip irrigation systems can be streamlined and obtained easily.

A method to determine flow uniformity along drip lateral from coefficient of variation of emitter flow rate and the average of absolute deviation was proposed [8]. A field experiment was performed for a lateral of 80 m length and 16 mm inside diameter with 160 emitters. The results indicated that the average difference between determined and measured friction losses was less than 3.5%.

A study was made to determine water use efficiency with modified closed-circuit trickle irrigation systems [9]. Field experiments were performed on maize for two different types of closed circuits at the Agriculture Research Fields, Agriculture

Faculty, Southern Illinois University, USA. The lengths of lateral lines were, 40, 60, and 80 m. Polyethylene pipes lateral lines with diameter of 16 mm, emitters' spacing of 30 cm, and built-in emitters 4 l/hr at 1 bar operating pressure were used. Horizontal and 2% slope conditions were considered. The results showed that saving in irrigation water widely varied between circuit types and laterals.

The combined effects of manufacturing variation and hydraulic variation on relative flow difference of drip emitters for a drip irrigation manifold-lateral unit were analyzed [10]. Variation of emitter manufacturing is a random variable that follows a normal distribution. This distribution can be expressed by emitter manufacturing coefficient of variation and a random variable that follows a standard normal distribution. The discharge of emitter was expressed by two parts. The first one is emitter coefficient of discharge and discharge exponent. The second part is a random term that takes into account the variation in emitter manufacturing. The relative flow difference formula in a drip irrigation manifold-lateral unit was derived based on hydraulic variations due to differences in elevation and head loss and the variation of emitter manufacturing. Based on this formula, a procedure for hydraulic design of drip irrigation manifold-lateral unit was proposed.

A study was made to compare between the closed and traditional drip irrigation systems [11]. This comparison includes lateral discharge and head losses. An experiment was conducted at the Water Management and Irrigation System Research Institute in Wadi El-Natroun station, Egypt. The difference between traditional and closed system is the second manifold pipe installed at the end of laterals to close the direction of water flow. The results showed that closed system has higher application efficiency, and emission uniformity compared with traditional one.

2. METHODOLOGY

The mathematical equations for the drip irrigation system is written in order to be solved using Engineering Equation Solver (EES). EES was developed by Bill Beckman and Sandy Klein, from the University of Wisconsin-Madison. EES is a general equation-solving program which can solve numerically thousands of coupled non-linear algebraic equations. The program can solve differential and integral equations, provide uncertainty analyses, do optimization, perform linear and non-linear regression, check unit consistency, convert units, and generate publication-quality plots.

The number of equations and number of unknowns must be the same. At each pipe, the discharge is unknown while, there is energy equation. At each node, the pressure is unknown, while there is a continuity equation. At each emitter, the exit discharge is unknown while, there is emitter equation (relation between emitter discharge and pressure head at the emitter) as shown in Eq. 3.

$$q_e = C \times h^k \tag{3}$$

Where q_e is the emitter discharge, C is a constant that depends on the emitter flow area and the flow regime, and (h) is the pressure head at the emitter.

The simulated subunit is 250 m long and 60 m wide Fig. 1. The manifold length is 250 m while the lateral length is 60 m. Tree spacing is 5m x 5m. Therefore, the number of trees per lateral is 12 and the number of laterals per manifold is 50. Each tree is provided with three emitters. Emitters used deliver 8 liters per hour when operated under a pressure head of 10 m. Hence, the required flow rate at each tree is 24 lit/ hr. The manifold diameter is 40 mm while the lateral diameter is 9 mm. These selected diameters are rather tight and are expected to produce excessive friction loss and consequently flow variation. The general practice of accepting a total pressure head difference of 20% of the operating pressure between extreme emitters within a subunit and splitting this total head loss equally between the manifold and the lateral, would result in diameters of 75 mm and 13 mm respectively for the manifold and lateral pipes. The pipes material is PVC with equivalent roughness height of 0.003 mm. Darcy-Weisbach equation is used to calculate energy losses in pipes as shown in Eq. 4. Three different alternatives for laterals are simulated; a) traditional end closed drip irrigation laterals (traditional), b) connected laterals at their ends using a second downstream manifold (connected), and c) looped closed circuit laterals (looped).

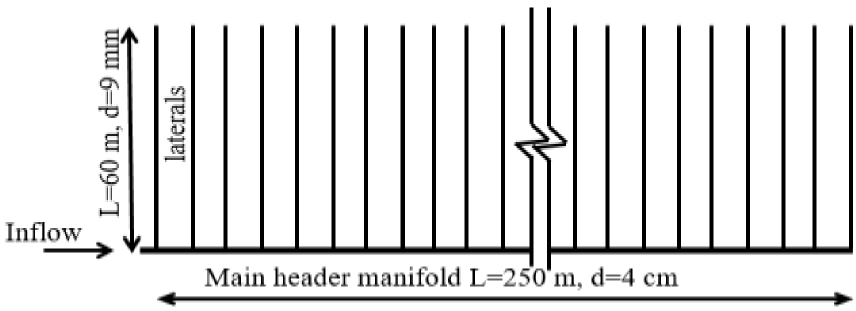
$$h_f = \frac{f\,L}{d} \times \frac{v^2}{2g} \tag{4}$$

Where h_f is the energy loss due to friction, L is the pipe length, d is the pipe diameter, v is the average velocity through the pipe, g is the gravity acceleration, and f is the pipe friction factor which is function of R_n and k_s/d. It can be calculated using Swamee–Jain equation 1976 as shown below [12].

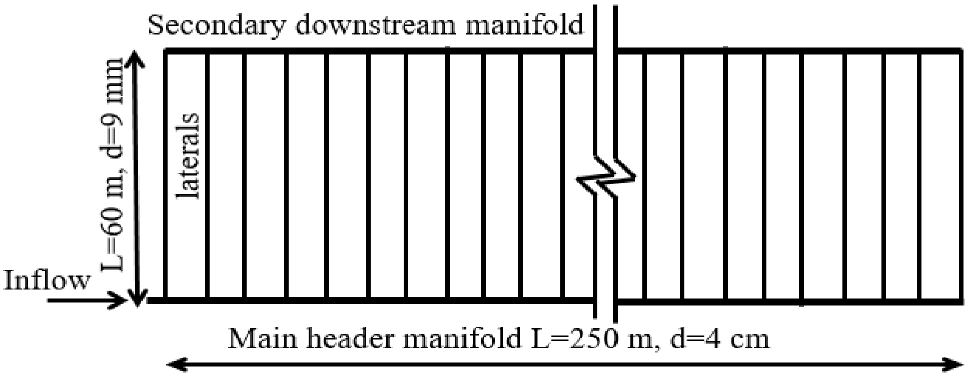
$$f= \frac{1}{[-2\times\log\left(\frac{Ks}{3.7\times d}+\frac{5.72}{R_n^{0.9}}\right)]^2} \quad (5)$$

where R_n is Reynolds number and K_s is the equivalent roughness height.

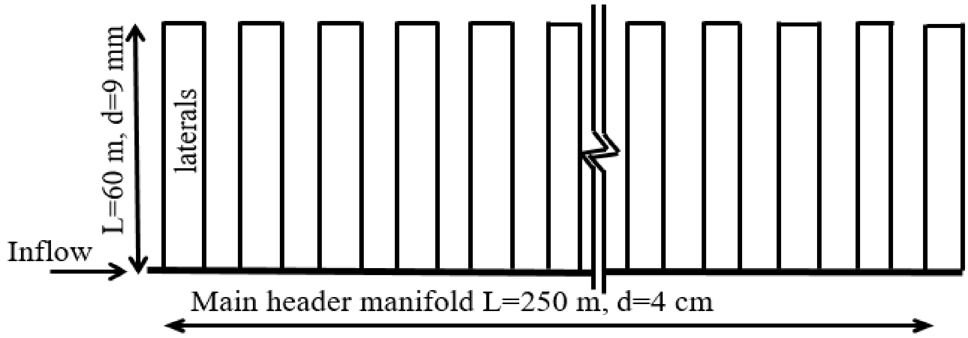
Sixty-six runs are studied using EES to find the pressure head and emitter discharge for all the emitters in the subunit. Christiansen uniformity coefficient C_u, relative flow variation q_{var}, and average emitter flow q for each run are then calculated. A summary of the analyzed runs, cases and alternatives is given in Table 1. Runs 1, 2, 3 reflect the impact of the exponent (x) in the emitter head – flow equation. Runs 2, 4, 5, 6, 7 show the impact of the inlet pressure head for the subunit. While runs 2, 8, 9, 10, 11, 12, 13 show the effect of the manifold slope, runs 2, 14, 15, 16, 17, 18, 19 show the effect of the lateral slope. Positive slope indicates an uphill and negative slope indicates a downhill condition. Runs 2, 20, 21, 22 show the effect of the diameter of the downstream manifold for the connected laterals alternative. Finally run 23 is for the study of the impact of clogged laterals where five laterals located 50, 55, 60, 65 and 70 m from the subunit entrance are assumed clogged at their inlets. Run 24 is for a relaxed subunit design where the lateral diameter is 13 mm instead of 9 mm and the manifold diameter is 75 mm instead of 40 mm. The operating head given in the third column of Table 1 is the starting pressure head at the subunit entrance [13].



(a) traditional



(b) connected



(c) looped

Fig. 1. Layout of the drip irrigation systems for the three lateral alternatives.

3. RESULTS AND DISCUSSIONS

Sixty-six runs are made using EES to find the pressure head and emitter discharge for all emitters in the drip irrigation subunit shown Fig. 1 and outlined in table 1 for the three lateral alternatives (traditional, connected and looped). The results showed that as the emitter exponent increases, the uniformity coefficient decreases for the three alternatives. Moreover, the connected laterals alternative has higher uniformity than traditional and looped laterals. In addition, the traditional and looped laterals have the same results and are equivalent (same uniformity coefficient, average pressure head, and average discharge). Figure 2 clearly shows that the minimum flow rate in connected laterals is greater than that of the traditional laterals. Hence, the alternative of connected laterals is better.

Increasing the pumping head leads to an increase in the uniformity coefficient for the three alternatives and the connected laterals has more uniformity than traditional and looped laterals (Table.1 and Fig.3). In addition, the traditional and looped laterals alternatives have the same results (same uniformity coefficient, average pressure head, and average discharge).

Increasing the manifold slope leads to an increase in the uniformity coefficient for the three alternatives when the slope is downward. The uniformity coefficient decreases by increasing manifold slope for uphill conditions (Table.1 and Fig. 4). In addition, the traditional laterals and looped laterals have the same results (same uniformity coefficient, average pressure head, and average discharge). Moreover, the connected laterals alternative has more uniformity than traditional and looped laterals except for a downhill manifold of -2.5% slope. This is due to the high emitters' discharges at the end of the manifold where water can reach the end from two paths (two manifolds) and there are high pressure heads at the end of the two manifolds due to the large difference in elevations.

Increasing the lateral slope leads to a decrease in the uniformity coefficient for the three alternatives for both downward and upward slopes (Table 1 and Fig. 5). Again, traditional and looped laterals are equivalent (same uniformity coefficient, average pressure head, and average discharge). Connected laterals has higher uniformity than traditional and looped laterals.

Decreasing the diameter of the second downstream manifold results in decreasing the uniformity coefficient (Table 1 and Fig. 6).

If there is clogging in the laterals (five laterals in the network) the uniformity coefficient decreases but the connected laterals alternative still has more uniformity coefficient than the other two alternatives (Table 1 and Fig. 7).

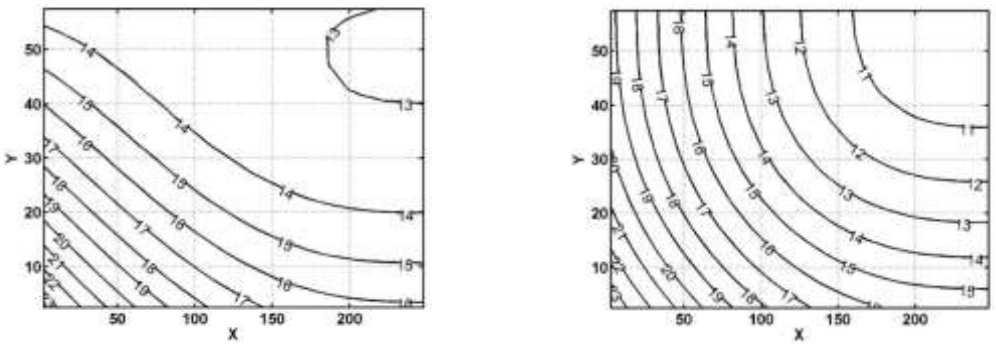
It is clear from the isolines of the emitter flow over the entire subunit, Fig. 2 through 7 that the flow rate is only adequate (close to 24 liters per hour) close to the subunit entrance. At the distal ends of the subunit (last emitters on the last laterals) the flow rate is very small, some 50 % of the required flow. This is a clear indication that the selected diameters of the manifold and lateral pipes are rather small producing excessive friction head loss. This sub-optimal condition was intentionally enforced to study the impact of using a non-traditional connected laterals at their ends. Figure 8 shows clearly that using a more relaxed design with larger manifold and lateral diameters produces high uniformities for all three alternatives.

Table 1 clearly shows that the uniformity coefficient and the relative discharge variation are inversely proportional. The very large values of q_{var} for cases 1 through 23 in Table 1 (sometimes more than 100%) is another indication that the studied network is very tight.

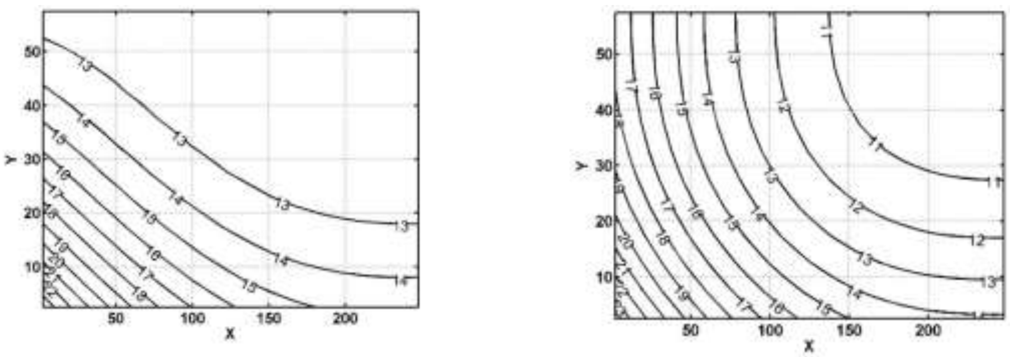
Table 1. Uniformity coefficient, relative discharge variation and average flow rate for the three lateral alternatives under different conditions.

No.	Emitter exponent	Head (bar)	Manifold Slope %	Lateral Slope %	Cu			q_{var}			$\bar{q}$ (l/hr)		
					Connected %	Traditional %	Looped %	Connected	Traditional	Looped	Connected	Traditional	Looped
1	0.3	1	0	0	88.5	82.3	82.3	0.71	0.92	0.92	15.0	14.7	14.7
2	0.5	1	0	0	88.4	82.9	82.9	0.84	1.01	1.01	13.9	13.7	13.7
3	0.75	1	0	0	88.0	82.5	82.5	0.96	1.13	1.13	12.8	12.6	12.6
4	0.5	0.6	0	0	82.5	76.8	76.8	1.23	1.42	1.42	11.3	11.2	11.2
5	0.5	0.8	0	0	86.4	80.6	80.6	0.97	1.16	1.16	12.7	12.5	12.5
6	0.5	1.2	0	0	90.6	85.1	85.1	0.69	0.85	0.85	14.6	14.4	14.4
7	0.5	2	0	0	94.2	89.8	89.8	0.44	0.56	0. 65	17.0	16.7	16.7
8	0.5	1	1.25	0	79.3	76.0	76.0	1.35	1.34	1.34	12.7	12.6	12.6
9	0.5	1	1	0	82.0	77.6	77.6	1.22	1.26	1.26	13.0	12.8	12.8
10	0.5	1	0.1	0	88.1	82.3	82.3	0.87	1.03	1.03	13.8	13.6	13.6
11	0.5	1	-0.1	0	88.7	83.1	83.1	0.82	0.99	0.99	14.0	13.8	13.8
12	0.5	1	-1	0	89.6	85.8	85.8	0.90	0.86	0.86	14.7	14.4	14.5
13	0.5	1	-2.5	0	85.2	88.4	88.4	1.09	0.73	0.73	15.8	15.5	15.5
14	0.5	1	0	2.5	83.9	79.5	79.5	1.02	1.23	1.23	13.4	13.2	13.2
15	0.5	1	0	1	86.8	81.6	81.6	0.91	1.09	1.09	13.7	13.5	13.5
16	0.5	1	0	0.1	88.3	82.6	82.6	0.84	1.02	1.02	13.9	13.7	13.7
17	0.5	1	0	-0.1	88.6	82.8	82.8	0.83	1	1.00	13.9	13.7	13.7
18	0.5	1	0	-1	89.8	83.5	83.5	0.80	0.95	0.95	14.1	13.9	13.9
19	0.5	1	0	-2.5	91.3	84.1	84.1	0.77	0.9	0.90	14.4	14.1	14.1
20	0.5	1	0	0	88.1	dsm=0.03		0.86			13.9		
21	0.5	1	0	0	86.9	dsm=0.02		0.92			13.8		
22	0.5	1	0	0	83.7	dsm=0.01		0.99			13.7		
23	0.5	1	0	0	84.9	73.4	73.4	1.23	1.9	1.90	13.0	12.6	12.6
24	0.5	1	0	0	98.3	98.1	98.1	0.08	0.10	0.10	22.7	22.2	22.2

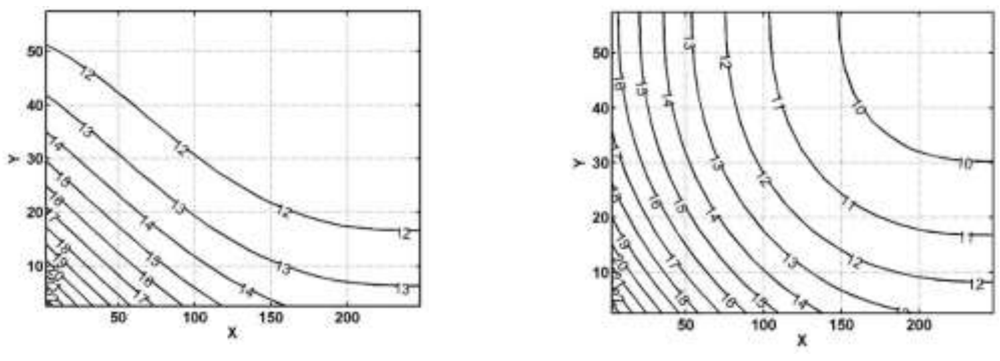
Note that cases 1 through 23 represent a tight network sizing where the manifold diameter is 40 mm, and the lateral diameter is 9 mm. Case 24 is for a more relaxed network sizing where the manifold diameter is 75 mm and the lateral diameter is 13 mm.



k=0.3



k=0.5

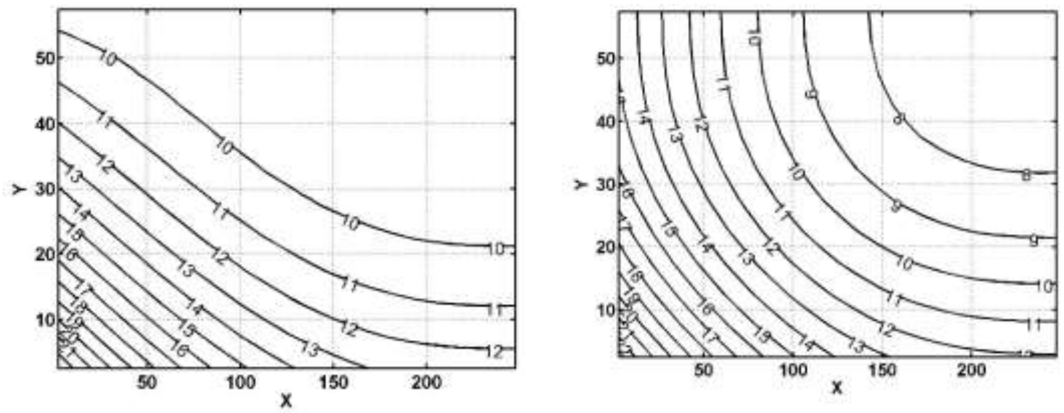


k=0.75

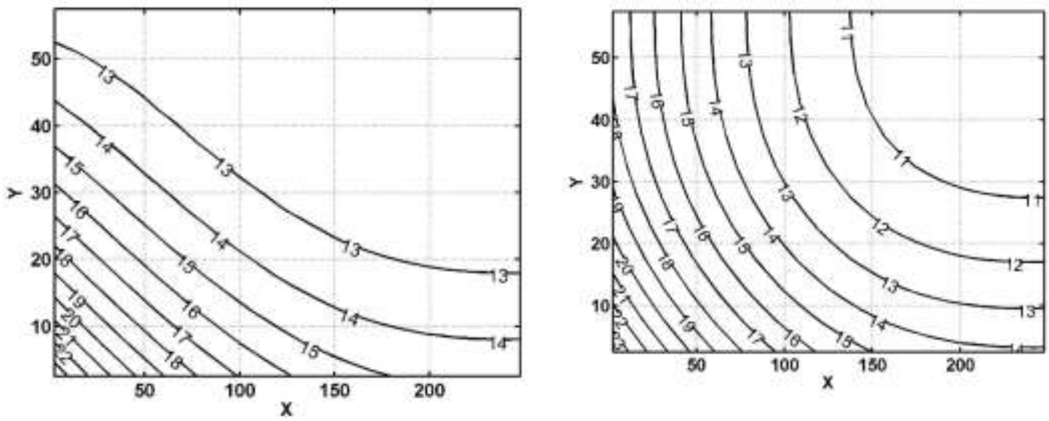
Connected laterals at their ends using a second downstream manifold

Traditional end closed drip irrigation laterals

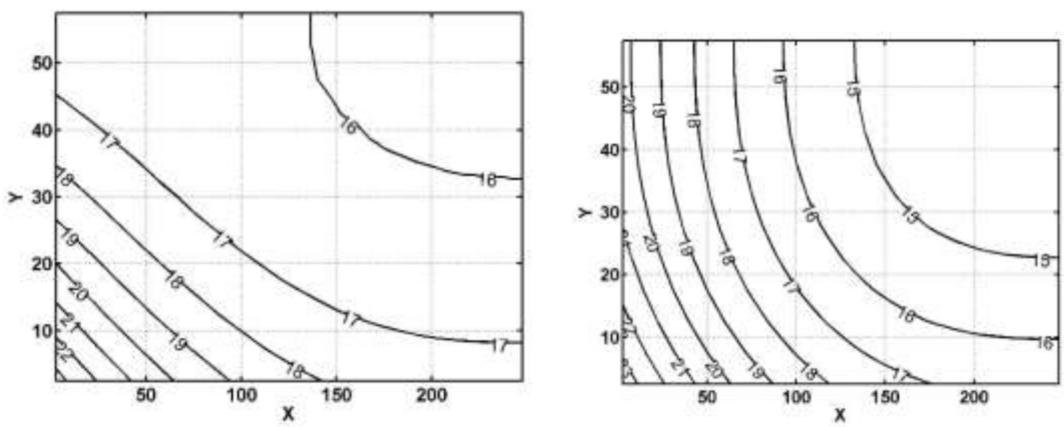
Fig. 2. Isolines of emitter out flow for two lateral alternatives with emitter exponent values (k) of 0.3, 0.5 and 0.75.



P= 0.6 bar



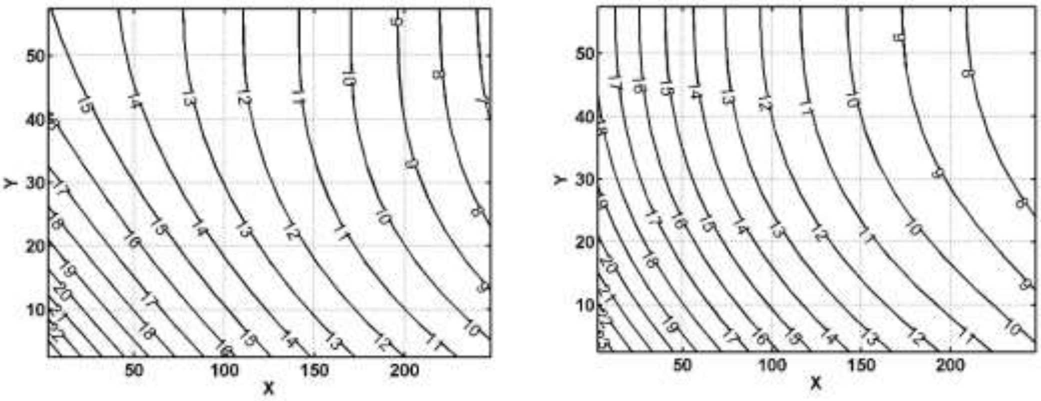
P=1 bar



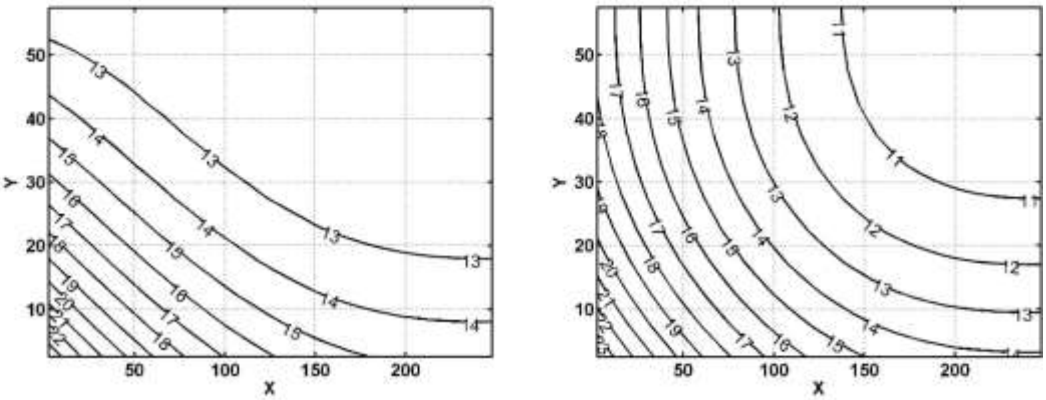
P=2 bar

Connected laterals at their ends using a second downstream manifold | Traditional end closed drip irrigation laterals

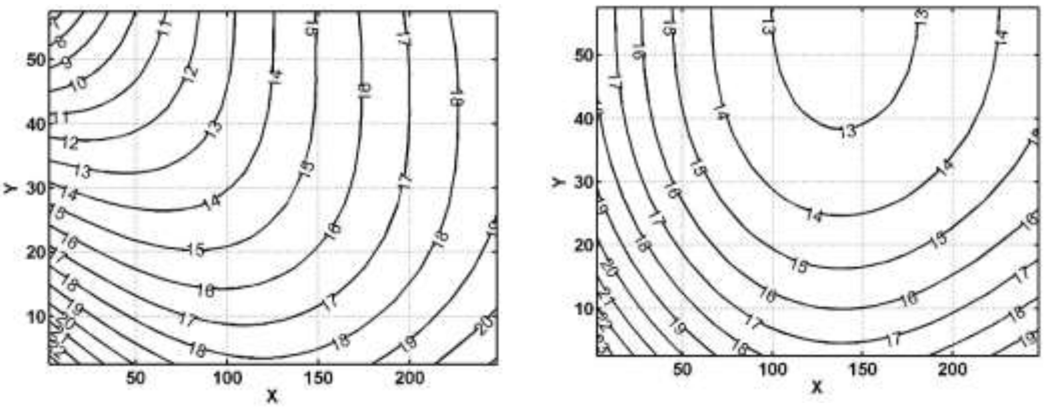
Fig. 3. Isolines of emitter out flow for two lateral alternatives with pressure head values of 0.6, 1 and 2 bar.



Manifold slope = 1.25%



Manifold slope = 0%

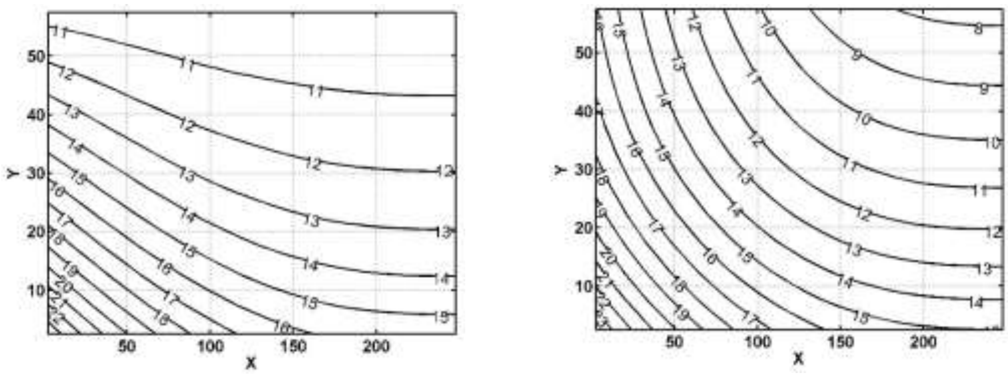


Manifold slope = -2.5%

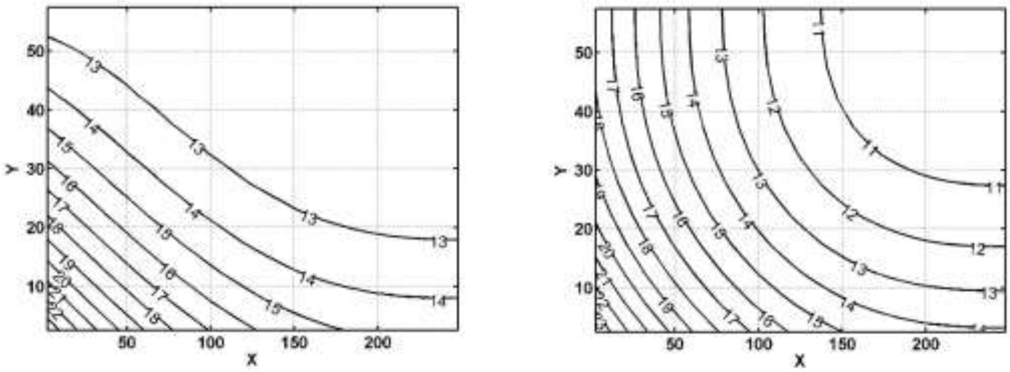
Connected laterals at their ends using a second downstream manifold

Traditional end closed drip irrigation laterals

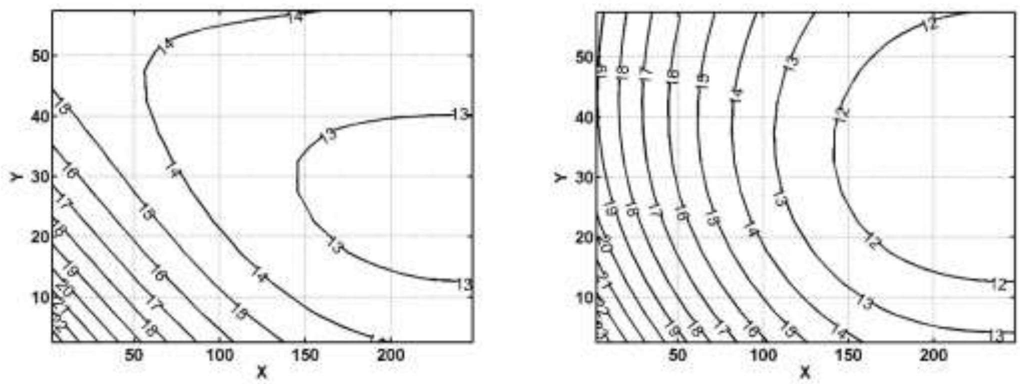
Fig. 4. Isolines of emitter out flow for two lateral alternatives with manifold slopes of 1.25%, 0.0% and -2.5%.



Lateral slope = 2.5%



Lateral slope = 0.0%

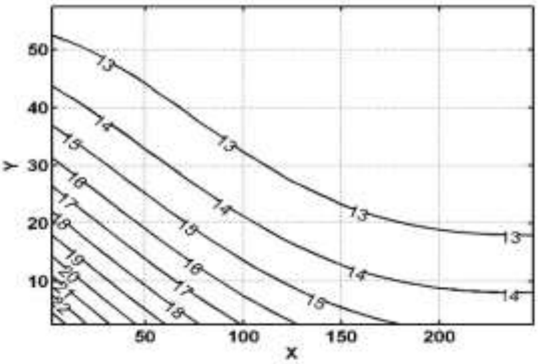


Lateral slope = -2.5%

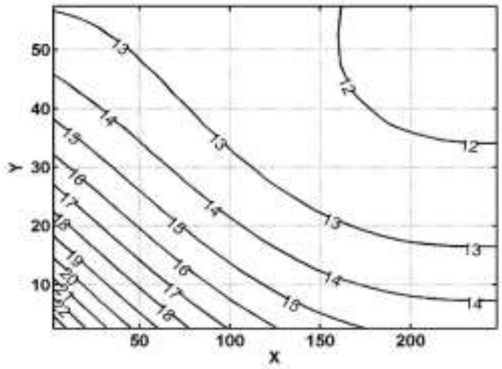
Connected laterals at their ends using a second downstream manifold

Traditional end closed drip irrigation laterals

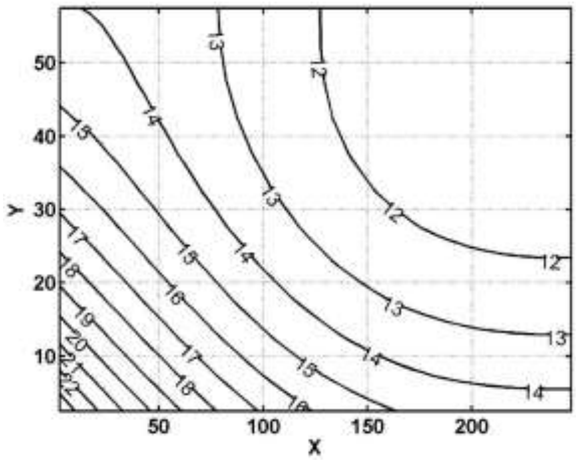
Fig. 5. Isolines of emitter out flow for two lateral alternatives laterals slope of 2.5%, 0.0% and -2.5%.



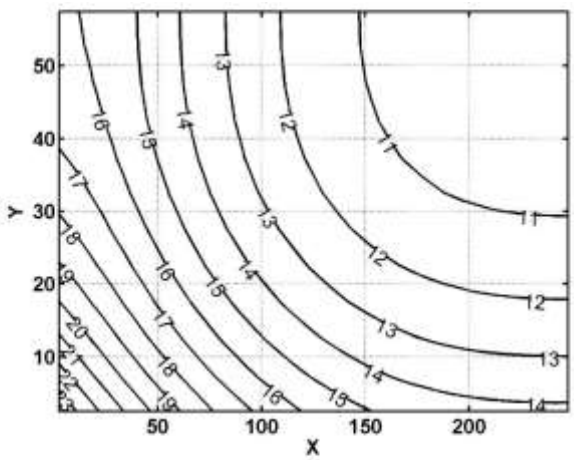
Diameter of second manifold= 4 cm



Diameter of second manifold= 3 cm

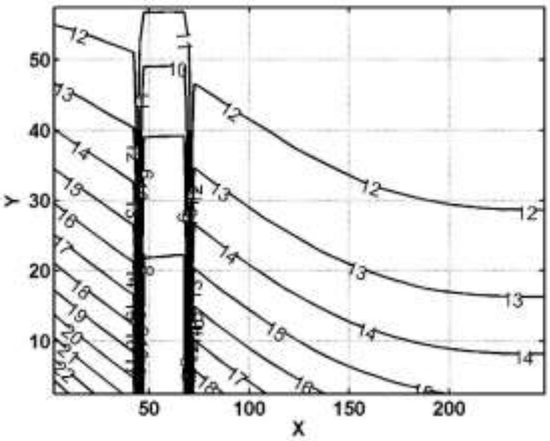


Diameter of second manifold= 2 cm

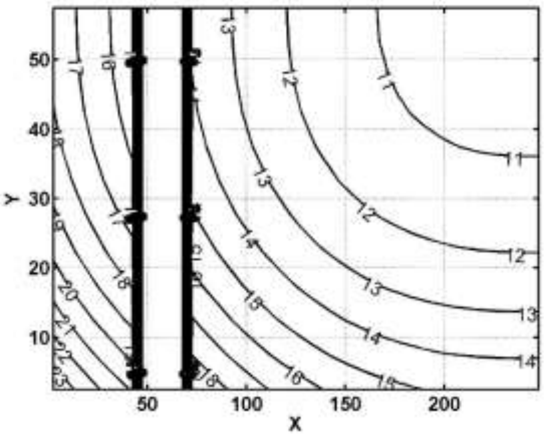


Diameter of second manifold= 1 cm

Fig. 6. Isolines of emitter out flow for connected laterals at their ends for second downstream manifold diameters of 4, 3, 2 and 1 cm.

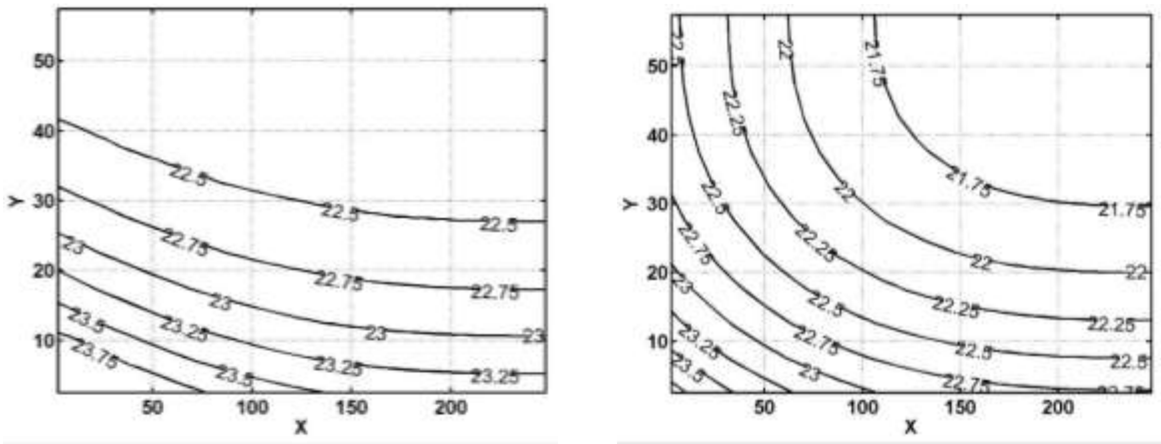


Connected laterals at their ends using a second downstream manifold (clogging of 5 laterals)



Traditional end closed drip irrigation laterals (clogging of 5 laterals)

Fig. 7. Isolines of emitter out flow for two lateral alternatives in case of clogged five lateral.



Connected laterals at their ends using a second downstream manifold

Traditional end closed drip irrigation laterals

Fig. 8. Isolines of emitter out flow for manifold diameter of 75 mm and lateral diameter of 13 mm.

4. SUMMARY AND CONCLUSIONS

Comparison between connected, traditional, and looped lateral alternatives is performed by investigating the hydraulics of the distribution systems and associated outflow variation. This is achieved using the Engineering Equation Solver (EES) software that can solve a set of nonlinear equations simultaneously. A drip irrigation subunit of 250 m x 60 m is analyzed using EES to determine emitters' pressure and discharge for 66 runs. These runs include different types of emitters, different pumping heads, different manifold slopes, different lateral slopes, different diameters of the second downstream manifold, and cases for lateral clogging. Christiansen uniformity coefficient and relative discharge variation are calculated for all cases to compare between connected, traditional and looped laterals alternatives. The results show that as the emitter exponent increases, the uniformity coefficient decreases for the three alternatives. Increasing manifold slope leads to increase in uniformity coefficient for the three alternatives under downhill conditions. The uniformity coefficient decreases by increasing manifold slope for uphill conditions. Increasing lateral slope leads to decrease in uniformity coefficient for the three cases for both downward and upward slopes. Decreasing the diameter of the second manifold results in reducing the uniformity coefficient. If there is clogging in the laterals (five laterals within the subunit) the uniformity coefficient decreases but the connected laterals alternative still has more uniformity coefficient than the other two alternatives. Therefore, connected laterals alternative is generally recommended as it results in higher uniformity coefficient than the other alternatives. Caution should be exercised when connecting the laterals at their ends for manifold running uphill. To improve the flow uniformity within a sub-unit, one can used relaxed pipe sizing, use higher operating pressure, employ pressure compensating emitters, and or connecting the laterals at their downstream ends using a second manifold. Although the main objective of this work is to show the impact of connecting the laterals at their ends to improve the flow uniformity, the procedures can be extended to design a subunit for a specific uniformity coefficient and adequate flow rate meeting the plant water requirements.

DECLARATION OF CONFLICT OF INTERESTS

The authors have declared no conflict of interests.

REFERENCES

1. Lamm, F.E., Ayars, J.E., and Nakayama, F.S., (Editors), "Micro-Irrigation for Crop Production", Development In Agricultural Engineering Vol. 13, 1st Edition, 2007.
2. Ortiz, C., "Annual Crop and Livestock Report: Imperial County", Office of the Agricultural Commissioner Sealer of Weights and Measures-Imperial County, CA, USA, 2018.
3. Zhang, L., Pute, W., and Delan, Z., "Hydraulic Design Procedure For Drip Irrigation Submain Unit Based On Relative Flow Difference", Irrigation Science Vol. 31, pp. 1065-1073, 2013.
4. Howell, T., and Hiler, E., "Designing Trickle Irrigation Laterals for Uniformity", ASCE Journal of Irrigation and Drainage Division, Vol. 100, pp. 443-454, 1974.
5. Gitlin, H., and Wu, p., "Drip Irrigation Lateral Line Network Design", Transactions of the ASAE, Vol. 25, pp. 675-685, 1982.
6. Pitts, D.J., Ferguson, A.J., and Wright, R.E., "Trickle Irrigation Lateral Line Design by Computer Analysis", Transactions of the ASAE., Vol. 29, No. 5, pp. 1320-1324, 1986.
7. Wu, P., "Energy Gradient Line Approach for Direct Hydraulic Calculation in Drip Irrigation Design", Irrigation Science, Vol. 13, No. 1, pp. 21-29, 1992.
8. Amer, K.H., and Gomaa, A.H., "Uniformity Determination in Drip Irrigation Lateral Design", Misr Journal of Agricultural Engineering, Vol. 20, No. 2, pp. 405-431, 2003.

9. Mansour, H.A., Tayel, M.Y., Lightfoot, D.A., and El-Gindy, A.M., "Energy and Water Saving by Using Modified Looped Laterals of Drip Irrigation System", Agricultural Sciences, Vol. 1, No. 3, pp. 154-177, 2010.
10. Zhang, L., Wu, P., and Zhu, D., "Hydraulic Design Procedure for Drip Irrigation Submain Unit Based on Relative Flow Difference", Irrigation Science, Vol. 31, pp. 1065-1073, 2013.
11. Nassar, A.A., Moursy, A.M., and, Rady, M.H., "Comparison between Traditional and Closed Drip Irrigation System in Engineering Aspects", Research and Technology Development of Sustainable Water Resources Management, 2016.
12. Swamee, P.K., and Jain, A.K., "Explicit Equations for Pipe-Flow Problems". Journal of the Hydraulics Division, Vol. 102, No. 5, pp. 657-664, 1976.
13. Tawfik, A. M., Bazaraa A. S., and El-Ayoty S. A., "Performance of Subsurface Drip Irrigation under Different Conditions", Journal of Engineering and Applied Science, Vol. 59, No. 1, pp. 23-37, 2012.

List of Symbols:

C: is a constant that depends on the emitter flow area and the flow regime

C_u: is Christiansen uniformity coefficient

d: is the pipe diameter

f: is the pipe friction factor which is function of R_n and k_s/d

g: is the gravity acceleration

h: is the pressure head at the emitter

h_f: is the energy loss due to friction

k: dripper exponent

K_s: is the equivalent roughness height

L: is the pipe length

n: is the number of emitters in the subunit

q_e: is the emitter discharge

q_i: is the outflow from an individual emitter (i)

R_n: is Reynolds number

v: is the average velocity through the pipe

$\bar{q}$: is the mean emitter flow

تحسين انتظام تصرفات النقاطات داخل وحدة الرى بالتنقيط

يقدم البحث مقارنة بين شبكات الرى التقليدية بالتنقيط المغلق فى نهاية المطاف، والخطوط الجانبية المتصلة عند نهاياتها باستخدام مجرى ثان، والشبكات الحلقية المغلقة لتحليل المكونات الهيدروليكية لأنظمة التوزيع، ولتقييم التوحيد الخارجى تم التوصل إلى حلول مفصلة للبدائل الثلاثة باستخدام برنامج حل المعادلات الهندسية (EES) الذى يمكن من حل مجموعة من المعادلات غير الخطية فى وقت واحد حيث يتم تحليل وحدة فرعية للرى بالتنقيط تبلغ مساحتها ٢٥٠ م × ٦٠ م باستخدام (EES) لتحديد الضغوطات والتصرفات الخارجة منها ل ٦٦حالة تغطى خصائص النقاط ، ورؤوس الضخ، والمنحدرات المتنوعة للماسورة الرئيسية، والمنحدرات الجانبية للخراطيم، وأقطار مختلفة للماسورة الثانوية، وحالة انسداد عدد قليل من الخطوط الجانبية عند مداخلها حيث تم حساب معامل تماثل كريستيانسين وفرق التدفق النسبى فى جميع الحالات للمقارنة بين للبدائل الثلاثة وأظهرت النتائج إلى أن الخطوط الفرعية المتصلة عند نهايتها بماسورة اخرى تحقق توحيدًا أعلى ما عدا فى حالات قليلة جدًا تتعلق بالتضاريس الأرضية وأن بديل الحلقات المغلقة يتطابق مع البديل التقليدى المغلق عند نهايته، ويعطى نفس معامل توحيد التدفق.