Misr J. Ag. Eng., 21 (2) : 139-153

Improving micro-irrigation efficiency by pressure regulated emission devices

G. A. Sharaf[1]

Abstract

The main objectives of this study are to define and analyze the factors that affect the flow deviation and the economic impact of applying pressure regulated emission devices (pressure compensating). To fulfill these objectives, an analytical procedure was developed to predict the flow variation due to the pressure distribution by applying the dimensionless energy gradient concept. Results revealed that lateral slope, manifold slope, emitter flow exponent and design allowable pressure variation were the most effective variables on the discharge variation. The relationship between the discharge variation and lateral slope, manifold slope, and emitter flow exponent was found to be linear function while power function was observed with the allowable pressure variation. The analysis indicated that, applying the pressure-regulated emitters could save water compared with regular emitters at the same operational conditions. For example, the excess water provided by turbulent flow emitter $(x = 0.5)$ is about 4.6% of the required water quantity under the economic design rule (20% allowable pressure variation of the emitter operating pressure) for leveled lands. This excess water is due to the pressure variation. To overcome this problem, it is recommended to use pressure regulated emitters (regulated system). The advantage of applying such systems extended to saving in equipment costs also. This was managed by increasing the regulated system inlet pressure, which causes additional cost of energy but permits using smaller lateral sizes. A comparison between the added cost for additional pressure and the saving in equipment was done to justify the increase of the regulated system inlet pressure. Through a case study by applying micro-sprinkler regulated system versus conventional one, the results indicated annual profits ranging between 55 to 313 LE/fed.year according to the system increased inlet pressure. For simplicity, a nomograph was developed to evaluate the economic feasibility.

Introduction

The increasing scarcity of water for irrigation plus high cost of solid-set sprinkler irrigation equipment promoted manufacturers and farmers to seek cheaper means of irrigation. The solution was the use of micro-irrigation, especially mini sprinkler in orchard. Shilo, Y. 1996 classified the advantages of the mini-sprinkler over the solid-set sprinkler system by the following; lower pressure requirements, lower discharge and precipitation rate, covering a large area in its operation, producing delicate drops, preventing runoff and crust formation, lowers the marginal water loss and lowering cost (about 60% less than solid set sprinkler). In micro-irrigation, roughly 90% efficiency has been achieved. With sprinkler

---

[1] Assoc. Prof. of Ag. Eng., Dept. of Soil & Ag. Chem. , Fac. of Ag. Saba Basha, Alex. Uni.

irrigation, the situation is different. Despite the fact that sprinklers have been greatly improved and more efficient equipment have been developed, there is still relatively large amount of water losses in sprinkler irrigation. The optimal pressure for many sprinklers is about 2 to 3 bar. This pressure is enough to operate mini-sprinkler efficiently with high uniformity even the pressure only 2 bar or lower in case of regulated mini-sprinkler.

A requirement for high application efficiencies involves regulated uniform flows from emitters (*which could be mini or micro-sprinklers, sprayers or tricklers*) placed on the laterals. Design and operational procedures as practiced are based on established trade-off between costs of energy (pressure) and materials (pipes) and are usually a basis for most optimal design systems as constrained by pressure, pipe and labor costs. These procedures, mainly due to pressure distribution, usually result in different degrees of uniform flow from emitter. Thus various means to regulate emitter flow and pressure were developed in order to reach fixed flow from emitters. The performance characteristics of a regulated emitter are intended to insure that the discharge does not vary with changes in pressure, particularly when this pressure is greater than a fixed operating pressure established by the regulation mechanism. If the inlet pressure is below that pressure, the emitter discharge does not vary with pressure. Also, in most practical cases, the operation of the emitter when the pressure is below the fixed operating pressure is relatively poor and not satisfactory. Meanwhile, a regulated emitter is normally operated under pressure higher than the fixed operational pressure called the minimal operating pressure. The development of pressure regulated emitters began since about 25 years ago. Water emission can be regulated by means of spring in dry chamber or discharge regulation by means of membrane/diaphragm in wet chamber (Kapan, A. 1996). Abdelatif (2003) developed a new self-controlled dripper. The dripper controls irrigation demands by means of small ceramic conic covered with rubber diaphragm that allows water flow when vacuum occurred in the ceramic conic due to soil matric potential.

Regular design procedures involve the determination of lateral and manifolds diameters on the basis of allowable pressure variation as a fraction of the emitter operating pressure (Benami and Ofen, 1984). With regulated emitters however, pressure differences do not significantly affect the emitter flow rates. Therefore, higher pressure differences are allowable, defined by minimum operating pressure as shown in Fig. (1). Consequently, the permitted head loss is higher allowing for smaller lateral and manifold piping diameters, resulting in significant saving in equipment cost. Applying smaller pipe sizes, increase the system inlet pressure and the energy cost.

The main objectives of this study are:

1 To define and analyze the factors that affect system flow deviation when using conventional emission devices.

2 To study the economic impact of applying pressure regulated emission devices instead of the conventional ones.

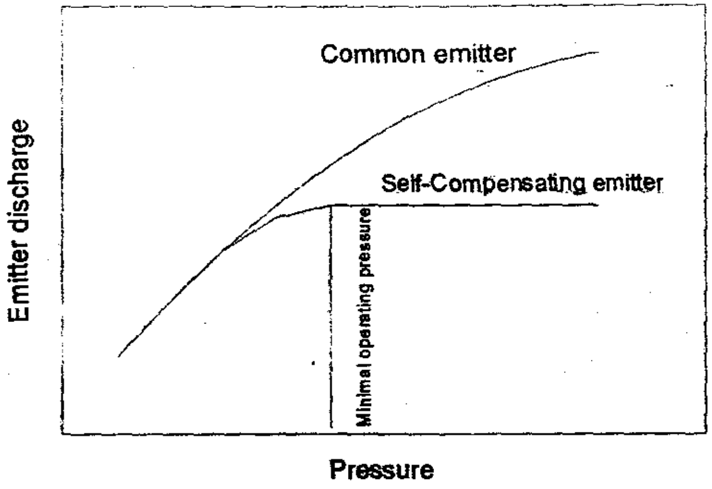

Fig. (1) Discharge versus pressure for common and self-compensating emitters (Balogh and Gergely, 1985).

Methodology

System flow rate deviation due to pressure variation:

The deviation of water flow rates due to pressure variation can be carried out by applying the dimensionless energy gradient concept, developed by Wu and Gitlin,1980. In this approach, the discharge from the line is assumed to be uniformly distributed along its length. Sharaf 2003 studied the validity of this concept. The shape of the energy gradient line is not straight but an exponential type curve can be expressed dimensionally as the energy drop ratio *R(i)* by the following equation:

$$R_i = 1 - (1 - i)^{m+1} \qquad (1)$$

Where:

i = detected length ratio from inlet (l/L).
m = flow rate exponent of the friction equation, m = 1.852 for Hazen-Williams.

Using this concept, the pressure variation along the lateral can be expressed as:

$$h_i = Hl_{in} - R_i \ Hf_l \pm i \ \Delta El \qquad (2)$$

Where:

h_i = pressure head at a given length ratio (i).
Hl_{in} = pressure head at the lateral inlet.
Hf_l = total pressure head loss along the lateral.
ΔEl = elevation difference along the lateral (- for upslope and + for downslope).

Since the emitter discharge at length ratio "i "is related to pressure head at length ratio "i" then the emitter flow rate can be calculated at various points along the lateral line once the lateral inlet pressure (Hl_{in}) is known. The same concept can also be used for manifold where lateral lines are considered similar to uniformly spaced emitters and Eq. (2) can be rewritten as:

$$h_j = Hm_{in} - R_j \ Hf_m \pm j \ \Delta Em \qquad (3)$$

Where:

h_j = pressure head at a given length ratio j on manifold

Hm_{in} = pressure head at the manifold inlet

Hf_m = total pressure head loss along the manifold

ΔEm = elevation difference along the manifold(- for upslope and + for downslope)

Combining Eq. (2) and (3) by replacing Hl_{in} by h_j to determine the pressure head at any point in the submain $h_{j,i}$ results in:

$$h_{j,i} = Hm_{in} - R_j\ Hf_m - R_i\ Hf_l \pm j\ \Delta Em \pm i\ \Delta El \qquad (4)$$

Since the estimation of flow depends on specific set of variables such as emitter characteristics, number and spacing of emitters and land slope, the typical water discharge variation due to pressure distribution or pressure variation can be determined with the following assumption:

1- The required emitter flow rate is the nominal flow rate (q_o) and the average pressure head is designed to be the emitter nominal operating pressure (h_o).

2- The emitter discharge is related to the available pressure head by the following equation:

$$q_{j,i} = k\, h_{j,i}^{\ x} \qquad (5)$$

Where:

k = coefficient that depends on nozzle size and dimensions.

x = emitter flow exponent, 0.5 for orifice type and 0.4 for sprayers (SCS,1982).

Therefore, the discharge of a subunit has (*N*) number of laterals along the manifold and (*n*) number of emitters along the lateral is:

$$\textit{Lateral flow rate } Q_j = \sum_{i=1}^{i=n} q_{j,i} \qquad (6)$$

$$\textit{Manifold flow rate } Q_m = \sum_{j=1}^{j=N} Q_j = \sum_{j=1}^{j=N} \sum_{i=1}^{i=n} q_{j,i} \qquad (7)$$

If pressure regulated emitter used or the emitter applied in not influenced by the change of pressure, then the subunit discharge will be $N*n*q_o$

3- The design criteria for economic pipe sizes is partitioning the allowable pressure variation (20% of the emitter nominal operating pressure) as 55% on lateral and 45% on manifold (Keller and Karmeli, 1975).

For more generalization of Eq. (4), the elevation differences ΔEl, ΔEm, the allowable pressure variation *APV* and the pressure inlet to the subunit (Hm_{in}) could be defined as a fraction of the emitter nominal operating pressure (h_o). Therefore, Eq.(4) could be rewritten as:

$$h_{j,i} = h_o/(1 - APV) - (.45*APV*h_o)R_j - (0.55*APV*h_o)R_i \pm ho*C1*j \pm h_o*C2*i \qquad (8)$$

Where:

$C1$ = manifold elevation difference as ratio of emitter operating pressure.

$C2$ = lateral elevation difference as ratio of emitter operating pressure.

Based on the above, the percentage of discharge variation of water due to the pressure distribution ΔQ_h along the subunit will be:

$$\Delta Q_h = \left[\frac{\sum_{j=1}^{j=N} \sum_{i=1}^{i=n} k\, h_{j,i}^{\ x}}{N\, n\, q_o} - 1 \right] x100 \qquad (9)$$

$$or \quad = \left\{ \frac{\sum_{j=1}^{j=N} \sum_{i=1}^{i=n} h_{j,i}^{\ x}}{N\, n\, h_o^{\ x}} - 1 \right\} x100 \qquad (10)$$

$$or = \left[\frac{\sum_{j=1}^{j=N} \sum_{i=1}^{i=n} \left[1/(1-APV) - 0.45 * APV * R_j - 0.55 * APV * R_i \pm C1 * j \pm C2 * i \right]^{x}}{n * N} - 1 \right] x100 \qquad (11)$$

Inspection of Eq. (11), it could be seen that the deviation of subunit discharge due to the pressure distribution effects dependant on *x*, *APV*, *N*, *n*, *C1* and *C2*.

Assuming that the flow rate is constant along the laterals during the irrigation time, then the deviation of water discharge (ΔQ_T) of the subunit due to the pressure variation during *T* hours of operation is:

$$\Delta Q_T = \frac{\Delta Q_h\, n\, N\, q_o\, T}{10^5} \qquad (12)$$

Where:

ΔQ_T = deviation of subunit water discharge (m^3).

q_o = emitter nominal flow rate (l /h).

Economical advantage of applying pressure regulated emitters:

Micro-irrigation lateral design can be classified in three types of design problems: (1) lateral lengths is unknown but pipe size is constrained; (2) pipe size is known but the lateral length is constrained and; (3) neither pipe size nor lateral length are constrained (Sharaf, 1996). Usually, pipe sizes are limited to standard pipe diameters. In this study, the design problem type (1) was applied to determine the lateral maximum length or the maximum allowable number of emitters on lateral for a given emitter, pipe size, slope and allowable pressure variation. Based on the above, the maximum pressure drop along the lateral and manifold are determined by:

$$\Delta hl = Hf_l \pm \Delta El \qquad (13)$$

$$\Delta hm = Hf_m \pm \Delta Em \qquad (14)$$

Where:

Δh = allowable pressure drop (m)

l, m = detected lateral and manifold respectively.

± = + for up slope and – for down slope

Applying a relationship relates the pressure drop and pipe length presented by Sharaf (2003) as:

$$\Delta h = \frac{a}{Pi - 2} L^{(Pi-2)} \qquad (15)$$

Where:

Pi = constant, 4.852 for applying Hazen-Williams Eq. at C =140 for $10^5 \geq Re \leq 10^7$

L = pipe length, m.

a = variable depends on diameter, flow rate, and spacing given by:

$$a = \frac{Ai}{D^{Pi}} \left(\frac{Q}{S} \right)^{Pi-3} \qquad (16)$$

Where:

Ai = constant (1.283 x 10^6)) when applying Hazen- Williams Eq. at C =140.

D = pipe diameter (mm).

S = outlet spacing, *Se* for emitter spacing (m) and *Sl* for lateral spacing (m).

Q = outlet discharge, q_o for emitter and *Ql* for lateral (l/s).

Solving Eq. (15) for lateral maximum length or maximum allowable emitters on lateral gives:

$$Ll = \left[\frac{\Delta hl \ (Pi - 2)}{a} \right]^{1/(Pi-2)} \qquad (17)$$

$$n = INT \left[\frac{Ll}{Se} \right] \qquad (18)$$

$$N = INT \left[\frac{SA}{n * Se * Sl} \right] \qquad (19)$$

Where:

INT = integer value.

SA = subunit area (for rectangular shape), taken as 4200 m^2 in the study.

The reason behind this analysis is to compare a subunit having the same number of regular or regulated emitters along lateral (*n*) at the same number of laterals along the manifold (*N*) to investigate the saving in laterals piping cost only. Assuming that the manifold size and emitter prices are the same in both cases. With spacing between laterals *Sl*, The total lateral lengths per unit area and the saving in laterals piping cost were estimated by the following equations:

$$TLl = n * N * Se \qquad (20)$$

$$SLPC = TLl(Ct_1 - Ct_2) \qquad (21)$$

Where:

TLl = total length of laterals per unit area (m), for rectangular subunit shape
$SLPC$ = saving in laterals piping cost (LE/fed.).
Ct_1 = cost of unit length of lateral due to applying regular emitter (LE/m).
Ct_2 = cost of unit length of lateral due to applying regulated emitter (LE/m) .

With regulated emitters an increase in system inlet pressure (Hm_{in}) is permitted allowing smaller lateral diameter. The increasing of inlet pressure means additional cost of energy, therefore, a comparison between the added cost for additional pressure and the saving in lateral piping costs should be made in order to justify the increase of system inlet pressure. The additional cost of energy (ΔCE), if the discharge per unit area (Q_f) and the system operation time is carried out in T hours, to provide additional head (ΔH) is given by the following equation:

$$\Delta CE = \frac{Q_f * \Delta H * T * C_{kw}}{367 * \eta} \qquad (22)$$

Where:

ΔCE = additional cost of energy (LE/fed.)
Q_f = discharge per fed. (m^3/fed.h)
ΔH = inlet head difference between regular and regulated systems (m)
T = system operating time (h/year)
C_{kw} = cost of energy unit (LE/kWh).
η = pumping efficiency (decimal).

The discharge per unit area (Q_f) and the operating time can be replaced by the applied depth of water (ADW), then Eq. (22) can be modified to be as follows:

$$\Delta CE = \frac{4.2 * ADW * \Delta H * C_{kw}}{367 * \eta} \qquad (23)$$

Where:

ADW = applied depth of water (mm/year)

The profitable replacement of reducing of lateral sizes by increasing the system inlet pressure, which can be applied with regulated emitters, was estimated by the followings:

$$AP = ASLPS \pm \Delta CE \qquad (24)$$

$$ASLPC = SLPC * CRF \qquad (25)$$

Where:

AP = annual profit of decreasing lateral size and increasing pressure (LE/year).
$ASLPC$ = annual saving of lateral pipe cost (LE/year).
$\pm$ = - means additional cost of energy, + is saving in energy cost.
CRF = capital recovery factor, (Jams,1988) calculated by the following equation:

$$CRF = \frac{ir(1+ir)^{LE}}{(1+ir)^{LE} - 1} \qquad (26)$$

Where:

ir = annual interest rate (decimal)
LE = life expectancy, Assumed as 5 years for plastic pipes.

Results and discussion

Effective variables on system discharge variation % (ΔQ_h):

Studying the variables in Eq. (11) that affect the discharge variation (ΔQ_h), showed that, unit shape factor (lateral to manifold length ratio), distance between emitters, distance between laterals, has no influence on discharge variation. Meanwhile, lateral slope ($C2$), manifold slope ($C1$), emission device flow exponent (x) and the design criteria (allowable pressure variation, APV) were the effective variables. Their effects were studied by setting constant design conditions as $APV = 20\%$, $x = 0.5$, $C1 = 0$, and $C2 = 0$, then changing each variable within applicable range while the others were constants. The APV changed from 5% to 35%, $C1$ changed from -0.2 to $+0.2$, $C2$ changed from -0.2 to $+0.2$, and x changed from 0.1 to 0.9. The results indicated a linear relationship between the discharge variation % (ΔQ_h) and lateral slope ($C2$), manifold slope ($C1$), and emission device flow exponent (x), while a power function with allowable pressure variation (APV) as shown in Fig. (2). The graph is useful to expect the amount of ΔQ_h due to the effect of $C1$, $C2$, APV and x quickly instead of solving the compound Eq. (11).

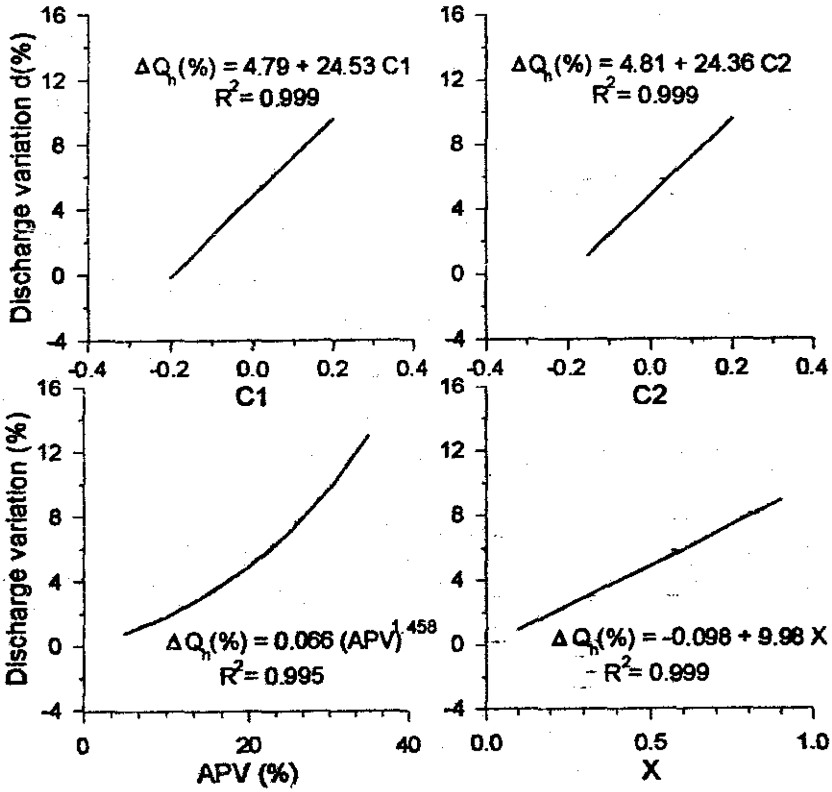

Fig.(2) : The discharge variation versus lateral slope, manifold slope and emission device exponent.

In case of using turbulent flow emission device ($x = 0.5$) for economic pipe sizes design (20% *APV* of h_o divided as 55% on lateral and 45% on manifold). A relationship between lateral and manifold slopes and the percent of discharge variation (ΔQ_h) is given in Fig. (3). The graph is useful to expect the discharge variation (excess or deficit) due to the pressure distribution at different slopes of lateral and manifold by applying regular emitter (x=0.5). For example, when the terrain is flat ($C1 = C2 = 0$), about 4.6 % excess water is expected than the required. This surplus amount of water could be prevented by the use of regulated emission devices.

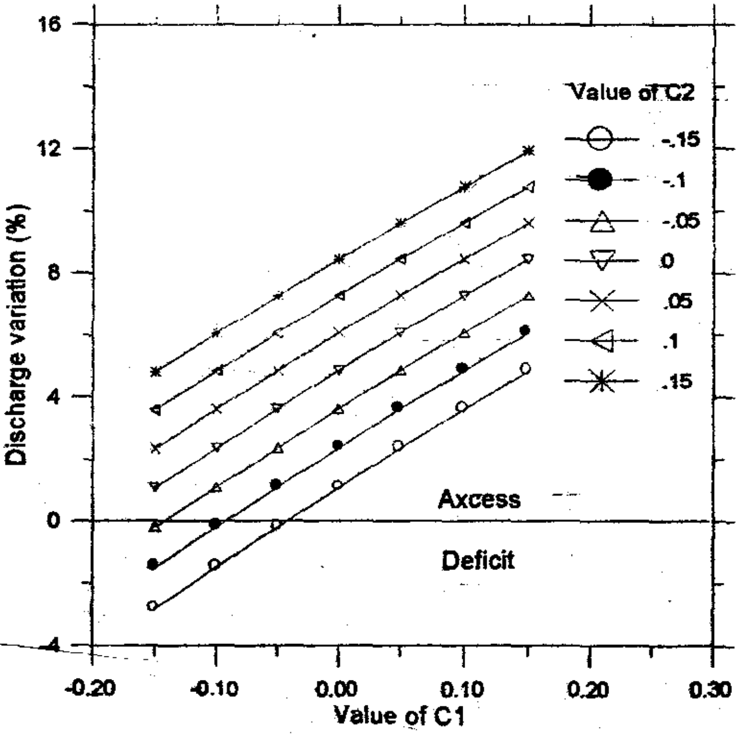

Fig.(3): Percent of discharge variation versus C1, C2 by applying regular emission devices

Economical consideration:

The analysis of economical impact of using the regulated emitters was investigated through a case study by applying a regular micro-sprinkler No. 8855 and regulated micro-sprinkler No. 8877 manufactured by Dan sprinkler[1]. The specifications of the micro-sprinklers under investigation are presented in Tab. (1). The prices of the emitter applied were the same. The spacing between the mini-sprinklers along the lateral (*Se*) is 4m, the distance between laterals (*Sl*) is 6m, the

---

[1] The mention of trade names of commercial products does not mean their endorsement or recommendation by the author.

land slope is zero in both lateral and manifold directions and the subunit area is one fed.

Tab. (1) The specifications of the Dan micro- sprinklers used for the study.

Flow rate q_o (l/h)	Regular mini-sprinkler No. 8855			Regulated mini-sprinkler No. 8877
	Operating head h_0 (m)	Discharge constants		Minimal operating head $h_{minimal}$ (m)
		x	k	
40	20	12.50	0.39	9
70	20	17.00	0.43	11
90	20	22.16	0.46	13
120	20	30.71	0.45	13

According to the economical criteria of the regular design (using regular mini-sprinkler), the APV is 20% of the pressure operating head (h_0), then the allowable head loss on lateral (Hf_l) will be 2.2 m (h_0 * APV* 0.55) and for manifold (Hf_m)1.8m (h_0 * APV * 0.45). Assuming the mini-sprinklers are mounted on Agri-spike (h_{sp}) 1m height with negligible head loss, the inlet pressure head to the regular system (Hm_{in}) will be 25m ($1.2\ h_0 + h_{sp}$). For regulated system (using regulated mini-sprinklers), five inlet pressure heads (Hm_{in}) were selected as, 20, 22, 24, 32 and 34 m. For the subunits have the same mini-sprinkler flow rate (q_o), same number of min-sprinklers on lateral (n), and same number of laterals on manifold (N), the manifold pipe size (D_m) will remain constant in both regular and regulated design. Therefore, the allowable head loss on the manifold of the regulated design will be 1.8m. Based on this, the allowable head loss on the regulated design laterals determined by ($Hf_l = Hm_{in} - h_{minimal} - Hf_m - h_{sp}$). The allowable head loss on lateral (Hf_l) in both systems under the same operational conditions is calculated and presented in Tab. (2). The permitted head loss along the regulated design lateral can be several times higher than that of the regular design. The allowable number of emitters (n) along the laterals were calculated based on four standard lateral sizes (Dl) as 16, 20, 25 and 32 mm. The internal pipe diameters of the selected pipe sizes were 13.2, 17, 20.8 and 26.8 mm respectively. The prices of the selected pipe sizes were 0.6, 0.8, 1.4 and 2.1 LE/m respectively. Adding 25% of the lateral piping cost as lateral accessories cost.

Tab. (2): Hf_l due to applying the regular and regulated mini-sprinklers according to the operation conditions and design criteria.

Flow rate (l/h)	Manifold friction loss Hf_m (m)	Manifold inlet pressure head Hm_{in} (m)					
		25 m	20 m	22 m	24 m	32 m	34 m
		Regular	Regulated				
		Allowable friction loss on lateral Hf_l (m)					
40	1.8	2.2	8.2	10.2	12.2	20.2	22.2
70	1.8	2.2	6.2	8.2	10.2	18.2	20.2
90	1.8	2.2	4.2	6.2	8.2	16.2	18.2
120	1.8	2.2	4.2	6.2	8.2	16.2	18.2

The allowable number of mini-sprinkler along the laterals for both regular and regulated design were calculated and presented in Tab. (3). The results demonstrate the possible use of smaller lateral size by applying the regulated micro-sprinkler with changing the system inlet pressure. The comparison of the two systems (regular and regulated) was based on selecting the subunits have same number of laterals on manifold, same number of the min-sprinkler on lateral and same mini-sprinkler flow rate (Compatible cases). The results are presented in Tab. (4). The calculations were based on 1000 mm of applied depth of water per year, 80 % pumping efficiency, cost of energy 0.25 LE/kWh and 0.31 capital recovery factor (CRF was estimated according to 17% annual interest rate and 5 years life expectancy of plastic pipes). As shown in Tab.(4), the annual profits is increased by increasing the regulated system inlet pressure. Energy saving was observed in some cases when the regulated system inlet pressure is selected lower than the regular design inlet pressure. This option of design could be managed to maximize the profit when the energy cost is high or when the saving in lateral piping cost is not significant.

Tab.(3): The allowable No. of regular and regulated mini-sprinklers on laterals for different system inlet pressures and pipe sizes

Manifold inlet pressure Hm_{in} (m)		Dl (mm)	Mini-sprinkler flow rate l/h			
			40	70	90	120
Regular	25	16	12	8	7	5
		20	19	13	11	9
		25	27	18	16	13
		23	42	29	24	20
Regulated	20	16	19	12	9	7
		20	30	21	14	11
		25	43	30	20	16
	22	16	21	13	10	8
		20	33	31	16	13
		25	47	30	23	19
	24	16	22	14	11	9
		20	35	23	18	14
		25	50	32	25	21
	32	16	27	18	14	12
		20	42	28	33	19
		25	60	40	32	27
	34	16	28	18	15	12
		20	44	29	24	19
		25	62	41	34	28

Tab. (4) The results of comparing regular and regulated micro-sprinkler applied.

Flow Rate l/h	No. of mini-sprinklers (n)	No. of Laterals (N)	D_m (mm)	Regular		Regulated		Comparative items			
				Hm_{in} (m)	D_l (mm)	Hm_{in} (m)	D_l (mm)	*SLPC* %	ΔCP %	AP LE/year	ΔQ_h %
40	19	9	90	25	20	20	16	25.00	20	70.89	3.57
	27	6	75	25	25	32	16	57.14	-28	175.85	3.52
	42	4	55	25	32	32	20	61.91	-28	313.49	3.43
70	13	13	110	25	20	22	16	25.00	12	63.12	3.93
	18	9	110	25	25	32	16	57.14	-28	175.85	3.93
	29	6	110	25	32	34	20	61.91	-36	312.42	3.89
90	11	15	125	25	20	24	16	25.00	4	54.73	4.20
	24	7	110	25	32	34	20	61.91	-36	305.33	4.18
120	9	19	160	25	20	24	16	25.00	4	56.59	4.08
	13	13	160	25	25	22	20	42.86	12	167.90	4.12

A developed nomograph for the economic feasibility:

While it is possible to use the above procedure to compare the additional cost of energy due to increasing the inlet pressure head and the saving in lateral pipe costs, it is time consuming since the variables are not constants. To simplify the process, a nomograph has been developed as shown in Fig. (4). The use of this nomograph is illustrated as follows:

- According to the energy price cost C_{kw}, move vertically in Quadrant II to the proposed difference in inlet pressure between the regulated and regular system (*ΔH*), then move horizontally in Quadrant I to the given applied depth of water per year (*ADW*), then establish a vertical line to Quadrant IV.
- According to the estimated value of saving in lateral costs (*SLCP*), move vertically to meet the capital recovery factor (*CRF*) in Quadrant III, then establish a horizontal line to Quadrant IV.
- The intercept of these two lines in Quadrant IV determines the economic feasibility of the regulated system compared with the regular system. If the intercept point lies down to the 45° line, then the system is economic to be used. Otherwise the intercept point is above the 45° line, then the regulated system is not economic compared with the regular system but still favors in water saving due to eliminating the effect of pressure distribution on changing the flow rates.

Illustrated on the nomograph, an economic feasibility of applying regulated versus regular system to add 1500 mm/year. The estimated value of saving in lateral costs was 750 LE/fed. due to increasing the inlet pressure by 12 m. The cost of energy and capital recovery factor were taken as, 0.5 LE/kWh and 0.3 respectively. As shown in Fig.(4), the intercept point lies below the 45° line, that means the regulated system is economic and the profit is 300 – 130 = 170 LE./fed. year.

Conclusion

Under regular operational conditions of pressurized irrigation system, varying flow rates through emission device causes decrease in irrigation efficiency due to pressure distribution. This decrease has more effects when the operational conditions are less satisfactory due to the topographical slopes and pressure changes. Excess in the water application due to the pressure distribution estimated as 4.6% for well-designed no sloped system used turbulent flow emission devices (x =0.5). This value could be changed due to lateral and manifold slopes, emission device flow exponent and the design criteria (allowable pressure variation). The effect of variation in flow rates may also extended to the application of fertilizers. Regulating the flows through the application of pressure regulated emission devices is therefore a desirable factor in increasing the irrigation efficiency and saving of both water and fertilizers. Regulation of flows under different inlet pressure heads, allows increasing pressure differences among the emission devices, therefore the permitted head loss along the lateral can be several times higher than of the regular design. Consequently, with using the regulated emission devices the lateral diameters can be smaller by one or two sizes in comparison with regular emission devices. The increasing of system inlet pressure head means additional cost of energy. Then, a comparison between the added cost for additional pressure and the saving in lateral piping cost must be done to justify the increase of the system inlet pressure. Through a case study of using mini-sprinkler regulated system versus normal one at the same operational conditions, the results indicated annual profits ranged between 55 to 313 LE/fed. year according to the selected inlet pressure of the regulated system. The study also indicated that, the application of regulated emission devices in some cases might be used to save the energy cost. This could be happened, when the regulated system inlet pressure is selected lower than the regular system inlet pressure. This is valid because in most cases the minimal operating pressure head for regulated emission devices is lower than the nominal operating pressure of the regular one at the same flow rate. This design option is useful in case of high energy price cost or when the saving in lateral piping cost is low. For simplicity, a nomograph was developed to study the economic feasibility of applying the regulated emission devices.

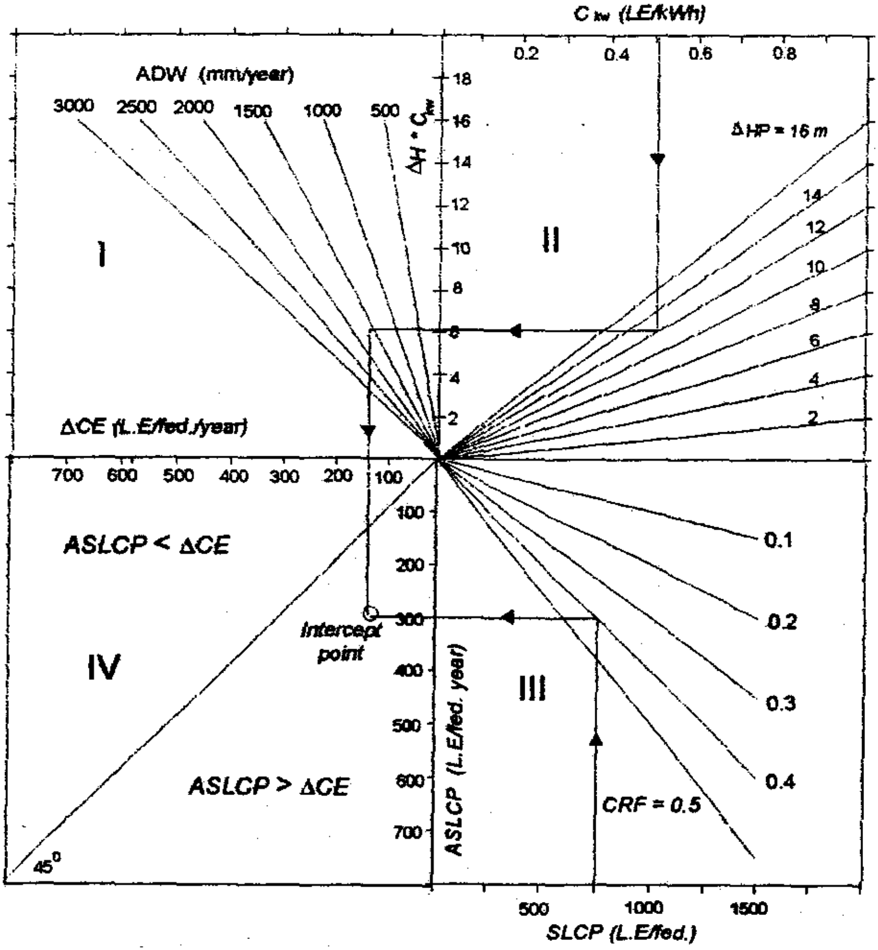

Fig. (4): Developed nomograph for economic feasibility of applying regulated versus regular emitters.

References

Abdelatif, Z. Y., 2003. Study of self-control dripper (Effect of outlet discharge on water flow). Misr J. Ag. Eng., 20 (1): 241-248.

Balogh, J and I. Gergely, 1985. Basic aspects of trickling irrigation. Budapest: Hungary: 280 pp.

Benami, A. ; A. Ofen, 1984. Irrigation engineering, IESP, Haifa, Israel.: 257 pp.

James, L. G., 1988. Principles of farm irrigation system design. John Wiley & Sons.Inc. :543 pp.

Kapan, A. 1996. The new generation of self – compensating drippers. The proceedings of the 7th International conference on water and irrigation. Tel Aviv, Israel , : 382-388.

Keller, J and D. Karmeli, 1975. Trickle irrigation design. Rain Bird Sprinkle Co. Glendora, Cal. :133 pp.

SCS, 1982. National Engineering Handbook Section 15 "irrigation" chapter 7 "Trickle irrigation" ,USDA: 129 pp.

Sharaf, G. A. 1996. Optimal design of trickle irrigation submain unit. Misr J. Ag. Eng., 13 (3):501 –515.

Sharaf, G. A. 2003. Evaluation of pressure distribution and lateral flow rates along drip tape lateral. Misr J. Ag. Eng., 20 (2): 542-556.

Shilo, Y. 1996. Micro-overhead irrigation – A new mini-sprinkler application. The proceedings of the 7th International conference on water and irrigation. Tel Aviv, Israel , : 349-353.

Wu, I. P. and H. M. Gitlin. 1980. Drip irrigation network design . ASAE Paper No. 80- 2521.

الملخص العربي

تحسين كفاءة نظام الري المصغر باستخدام الموزعات المعدلة للضغط

جمال شرف[1]

يغلب على نظم الري المتطورة عدم انتظام توزيع المياه أو الاختلاف فى التصرف فى الحقل من مكان إلى آخر نتيجة التغير فى الضغط لعوامل عدة منها طبوغرافية الأرض و فواقد الضغط نتيجة الاحتكاك و الفواقد الثانوية و الانسداد لأجهزة بث المياه ، ونتيجة لذلك أنتجت بعض الموزعات التى تقوم بتعديل الضغط للحفاظ على ثبات التصرف. واصبح شائعا أهمية استخدام هذا النوع من المنقطات فى الحفاظ على ثبات التصرف مع تغير الضغط دون التعرض لبعض الجوانب الإيجابية الأخرى الناتجة عن استخدامها. وبالتالي كان الغرض من هذه الدراسة هو تحليل بعض العوامل التى تؤثر على الاختلاف فى التصرف و إظهار أهمية استخدام الموزعات المعدلة للضغط والتى قد تؤدى تحت ظروف تشغيل معينة إلى توفير فى استهلاك الطاقة بجانب توفير المياه وخفض التكاليف الأولية ولاسيما تكاليف خطوط الري. و من دراسة العوامل التى تؤثر على اختلاف تصرف وحدة الرى عن التصرف المطلوب

---

[1] استاذ مساعد الهندسة الزراعية – قسم الاراضى والكيمياء الزراعية – كلية الزراعة –سابا باشا – جامعة الاسكندرية.

نتيجة تغير الضغط على خطوط الرى، أظهرت النتائج، أن شكل ومساحة الحقل, تصرف المنقط, المسافة بين المنقطات, المسافة بين الخطوط ليس لها تأثير على قيمة التغير ف التصرف عن التصرف المطلوب. بينما طبوغرافية الأرض ف اتجاه خطوط الري وخط التوزيع بالإضافة إلى معامل المنقط لها تأثير معنوي و خطى على التغير ف التصرف عن التصرف المطلوب. كما تبين أيضا أن الفاقد ف الضغط المسموح به(قاعدة التصميم) من العوامل المؤثرة و أن العلاقة بينهما علاقة اسية. أوضحت الدراسة أن باستخدام المنقطات المعدلة للضغط يمكن التغلب على التغير ف التصرف عن التصرف المطلوب و الناتج عن توزيع الضغط على خطوط الرى والذي قد يساعد ف كثير من الأحوال على توفير قدر من المياه تعتمد قيمته على العوامل السابقة. أما بالنسبة إلى للجانب الاقتصادي لاستخدام مثل هذه المنقطات فمن خلال دراسة حالة تبين انه من الممكن زيادة الضغط عند مدخل وحدة الري لإضافة ضغط التشغيل للمنقطات والتغلب على فواقد الضغط لخط التوزيع و ميول الأرض والمتبقي يستخدم ف تصميم خط الري (الطول أو القطر). وبمقارنة ذلك بنظام يستخدم الموزعات العادية ولها نفس ظروف التشغيل تبين انه من الممكن أن تقل أقطار خطوط الرى بشكل كبير مما قد يوفر ف التكاليف الأولية، لكن الزيادة ف الضغط قد تضيف تكاليف إضافية عن النظام العادي. وبذلك تمت المفاضلة بين الزيادة ف تكاليف الطاقة نتيجة زيادة الضغط والنقص ف التكاليف الأولية لخطوط الرى عن طريق حساب العائد السنوي. فتبين من النتائج أن العائد السنوي من استخدام المنقطات المعدلة للضغط يزداد بزيادة فرق الضغط المستخدم وتتراوح من ٥٥ الى ٣١٣ حنيه/ فدان سنويا حسب فروض الدراسة، هذا بالإضافة إلى إمكانية توفير ف استهلاك المياه. ولتيسير المقارنة الاقتصادية بين استخدم المنقطات المعدلة للضغط والمنقطات العادية, تم عمل مخطط (nomograph) يساعد ف أحراء هذه العملية بسرعة وسهولة ويسر.