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# Evaluation of Local Head Loss for Non Pressure Compensating Online Emitters and Pressure Compensating Inline Emitters in Drip Irrigation Laterals

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***Abstract—***

***In drip irrigation system, in laterals having inline as well as online emitters, the head loss along the lateral lines strongly affects the head available at emitter nozzles. This experimental study is conducted to evaluate local head loss in drip irrigation laterals with non pressure compensating online emitters and pressure compensating inline emitters. For determination of local losses for non pressure compensating online emitters in drip irrigation laterals, laterals of different diameters(12mm, 16m, and 20mm) with different emitter spacing's ( 20cm, 40cm and 60cm) at different operating pressures( 10m, 8m and 6m) were considered for laboratory experiments. Similar experiments were conducted for pressure compensating inline emitters in drip irrigation laterals.***

***The results of the experimental study were analyzed for assessment of the reliability of local loss evaluation procedure by comparing the measured and the estimated total head losses. Also the effect of different diameters of laterals as well as effect of different operating heads on total head loss in the drip irrigation lateral was studied. The study showed that the head loss verses diameter/spacing is around best fit parabola with satisfactory comparison of the estimated and measured head loss. The estimated total head loss is found to be reasonably accurate and the equations adopted can be used for estimation purpose.***

***Keywords**— Local loss, Minor loss, Drip irrigation, Lateral loss, Emitter loss*

## I. INTRODUCTION

Drip irrigation, also called trickle irrigation, is the method of delivering water at low volume in plant root zone through a pressurized pipe network. In the drip irrigation system, precise amount of water is applied to replenish the depleted soil moisture at frequent intervals, for optimum plant growth. Therefore, losses by deep percolation and evaporation are minimized. Presently it is the most efficient method of irrigation with typically 90 % efficiency, while sprinkler systems are around 75-85 % efficient.

The drip system uses pipes, tubes, filters, emitters and ancillary devices to deliver water to specific sites at a point or grid on the soil surface. The water is distributed through small pressure dissipating devices called emitter mounted at predetermined intervals on relatively small diameter pipes called laterals.

The drip irrigation design needs accurate evaluation of both the pipe friction loss and local loss due to the barb protrusions of the drippers into the laterals. This study includes assessment of the reliability of local loss evaluation procedure by comparing the measured and the estimated total head losses. It also includes effect of different diameters of laterals and operating heads on total head loss in the drip irrigation laterals.

### *A. Friction Loss*

The loss of energy due to friction is the major loss because in case of long pipelines it is usually much more than the loss of energy incurred by other causes. Estimation of friction loss in drip lateral pipes is an important aspect in the hydraulic design of drip irrigation system. Hydraulic friction loss in pipelines directly affects pipe diameter size and pump size, as well as the hydraulic balance of networks. Darcy-Weisbach equation is commonly used for computing the loss of head due to friction in pipes.

### *B Local Loss*

The local losses of energy are those which are caused on account of the change in the velocity of flowing fluid (either in magnitude or direction). In case of long pipes these losses are usually quite small as compared with the friction loss and hence these are also termed as 'minor losses'.

Design of a drip irrigation system consisting of laterals needs accurate evaluation of both the pipe friction loss and the loss due to the barb protrusion of the drippers into the laterals. Many researchers [1] [3] [6]. highlighted the importance of considering local losses when more number of emitters are installed along the laterals. In case of inline and online emitters, local loss is due to the turbulence consequent to protrusion of emitter barbs into the pipe flow and due to both the contraction and the expansion of flow stream lines at the emitter connections. Recently, Yıldırım [7] presented a simple analytical procedure for hydraulic design of trickle laterals. It takes into consideration the effect of minor head losses expressing the amount of minor head losses as a fraction of the kinetic head, as well as the effect of the emitter outflow non-uniformity, the kinetic head change, the number of emitters, and different uniform line slopes on the lateral hydraulic computations. For any desired uniformity level, the analytical procedure gives one, an opportunity to evaluate the influence of local energy loss on the pipe geometric characteristics (pipe size and length) and on the corresponding hydraulic variables (operating inlet and downstream end pressure heads and total energy losses). The earlier studies for different design combinations revealed that, in some design cases, neglecting minor losses may lead to erroneous designs of the lateral diameter and length. Also it has been seen [4] that inline emitters cause the contraction and subsequent enlargement of flow streamlines due to the protrusion of emitter barbs into the flow which are responsible for local loss in laterals.

## II. METHODOLOGY

The loss due to friction in pipe flow is calculated by using Darcy-Weisbach formula.

$$H_f = \frac{fLV^2}{2gD}$$

Where,

$H_f$ = head loss due to friction (m)
f = darcys friction factor
L = length of lateral (m)
V = mean flow velocity (m /sec)
D = inner diameter of lateral(m)
g = gravitational acceleration (m/ sec$^2$)

The Darcy-Weisbach equation includes a dimensionless friction factor '$f$' that is a function of the Reynolds number and the roughness of the pipe. The friction factor can be expressed by an equation [5].

$$\boldsymbol{f = 0.302R^{-0.25}}$$

R = Reynolds number = $\frac{\mathbf{VD}}{v}$
f = friction factor.
V = velocity of flow, m sec**-1**
D = inner diameter of lateral, m
$v$ = kinematic viscosity, m2 sec-1. = $\frac{\boldsymbol{\mu}}{\boldsymbol{\rho}}$
μ = dynamic viscosity of water, dyne-sec cm$^{-2}$
ρ = mass density of water, gm cc$^{-1}$.

The value of dynamic viscosity for the measured temperature of water may be obtained from the following relationship

$$\boldsymbol{\mu = \frac{0.0179}{1+0.03368T0.000221T^2}}$$

T = temperature of water, °C.

### *A. Local loss coefficient*

Local loss coefficient, denoted by 'α', is dependent on the connection geometry (shape and dimensions). The 'α' coefficient can be estimated as a function of parameters such as acceleration due to gravity, local loss per dripper and velocity [5].

$$H_{Li} = \alpha \frac{v_i^2}{2g}$$

Hence,

$$\alpha = \frac{2 \times g \times H_{Li}}{v_i^2}$$

Where,

$v_i$ = mean velocity along the lateral immediately downstream of the (i+1)$^{th}$ emitter, (m/s)

### *B. Estimation of friction losses*

The total friction losses between the first and the last emitter of the lateral, $H_f$,, is estimated as [5].

$$H_f = 0.0235\,\vartheta^{0.25} \frac{q_{av}^{1.75}}{D^{4.75}} S_d \sum_{i=1}^{N-1} (i)^{1.75}$$

Where,

 

ν = kinematic viscosity of water, ($m^2/s$)
N = number of emitters installed along the lateral
$q_{av}$ = average flow rate of a single emitter, ($m^3/s$)
D = inner diameter of lateral, (m)
$S_d$ = dripper spacing, (m)
i = dripper number counted from the downstream end of the lateral.

***C. Estimation of discharge from the emitter***

The discharge from the emmiter is estimated from the equation,

$q = kP^x$ …….. [2]

Where, q = discharge of dripper, ($m^3/s$)
P = operating pressure head, (m)
k = flow coefficient
x = emmiter exponent

To estimate emitter exponent x, the following is the mathematical analysis.

$q = kP^x$

$k = \frac{q}{P^x}$

Taking log on both sides,

$\log k = \frac{\log q}{x \log P}$

or $\log k = \log q - x \log P$

or K = $\log q - x \log P$ here, K = $\log k$

Consider regression analysis, in which we have,

$a = \bar{Y} - b\bar{X}$

Where,
a = K
$\bar{Y} = \log q$
$\bar{X} = \log p$
b = x

In the regression analysis,

$$b = \frac{\sum X_i Y_i - \frac{1}{n}(\sum X_i)(\sum Y_i)}{\sum X_i^2 - \frac{1}{n}(\sum X_i)^2}$$

Where,
$X_i = \log P_i$
$Y_i = \log q_i$
b = x

$$x = \frac{\sum(\log P_i)(\log q_i) - \frac{1}{n}(\sum \log P_i)(\sum \log q_i)}{\sum(\log P_i)^2 - \frac{1}{n}(\sum \log P_i)^2}$$

Where, $P_i$ = operating pressure, ($kg/cm^2$)
$q_i$ = mean of observations of discharge, (lph)
n = total number of operating pressure applied.

***D. Estimation of local losses***

Total local losses along a lateral, $H_L$, in which N emitters are installed, can be similarly calculated as the sum of local losses $H_{Li}$, at the $(i+1)^{th}$ emitter, obtained considering constant outlet flow rate $q_{av}$ [5].

$$H_L = \sum_{i=1}^{N-1} H_{Li} = \alpha \frac{8}{g\pi^2} \frac{q_{av}^2}{D^4} \sum_{i=1}^{N-1} (i)^2$$

Where,
α = local loss coefficient

***E. 2.5 Estimated total head loss***

Estimated total head loss along the lateral '$H_{Te}$' is calculated by,

$H_{Te} = H_f + H_L$

 

Where,
$H_f$ and $H_L$ are estimated using above equation.

## III. RESULTS AND DISCUSSION

### A. *At operating pressure head of 10 m*

Table-1 shows the comparison between the measured ($H_{Tm}$) and estimated total head losses ($H_{Te}$) for the Type-A online and Type-B inline laterals examined at operating pressure head (P) of 10 m. Fig.1 (a & b) shows that the points are around the best fit parabola for measured and estimated loss with $R^2$ value for Type-A online laterals being 0.936 and 0.934 respectively. Similarly for Type-B inline laterals, $R^2$ values are 0.975 and 0.990. Differences between the estimated and measured head losses, expressed as a percentage of the measured values are indicated in Table-1 which vary around -1.6% to -20.0%.

### B. *At operating pressure head of 8 m*

The Table-2 shows the comparison between the measured ($H_{Tm}$) and estimated total head losses ($H_{Te}$) for the Type-A online and Type-B inline laterals examined at operating pressure head (P) of 8 m. Fig.2 (a & b) shows that the points are around the best fit parabola with $R^2$ value for Type-A online laterals to be 0.940 & 0.924 respectively, and for Type-B inline laterals $R^2$ values are 0.966 and 0.990. Differences between the estimated and measured head losses, expressed as a percentage of the measured values as indicated in Table-2 vary between -2.8% to -22.5%.

### C. *At operating pressure head of 6 m*

The Table-3 shows the comparison between the measured ($H_{Tm}$) and estimated total head losses ($H_{Te}$) for the Type-A online and Type-B inline laterals examined at operating pressure head (P) of 6 m. Fig.3 (a & b) shows that the points are around the best fit parabola with $R^2$ value for Type-A online laterals to be 0.937 & 0.924 respectively, and for Type-B inline laterals, $R^2$ values are 0.976 and 0.991. Differences between the estimated and measured head losses, expressed as a percentage of the measured values as indicated in Table-3 vary between -0.4% to -25.5%.

Table -I: Comparison between the $H_{tm}$ and $H_{te}$

| **For 10 m operating pressure** | | | | | | |
|---|---|---|---|---|---|---|
| **Diameter-Dripper Spacing (mm-cm)** | **Measured Head loss $H_{Tm}$ (m)** | **Friction loss (Hf), in m** | **Total local loss along lateral, HL in m** | **Estimated head loss $H_{Te}$ (m)** | **$(H_{Te}-H_{Tm})/H_{Tm}$ %** | **$(H_{Te}-H_{Tm})/P$ %** |
| ONLINE LATERALS **TYPE-A** | | | | | | |
| 12-20 | 3.599 | 3.447 | 0.0936 | 3.54 | -1.61 | -0.58 |
| 12-40 | 1.526 | 1.396 | 0.0305 | 1.43 | -6.51 | -0.99 |
| 12-60 | 0.876 | 0.711 | 0.0181 | 0.73 | -16.77 | -1.47 |
| 16-20 | 0.940 | 0.905 | 0.0140 | 0.92 | -2.20 | -0.21 |
| 16-40 | 0.278 | 0.259 | 0.0031 | 0.26 | -5.56 | -0.15 |
| 16-60 | 0.143 | 0.123 | 0.0012 | 0.12 | -12.89 | -0.18 |
| 20-20 | 0.270 | 0.260 | 0.0018 | 0.26 | -3.19 | -0.09 |
| 20-40 | 0.085 | 0.078 | 0.0003 | 0.08 | -7.63 | -0.06 |
| 20-60 | 0.046 | 0.038 | 0.0001 | 0.04 | -17.67 | -0.08 |
| INLINE LATERALS **TYPE-B** | | | | | | |
| 16-40 | 0.050 | 0.045 | 0.0010 | 0.05 | -8.15 | -0.04 |
| 16-60 | 0.023 | 0.021 | 0.0005 | 0.02 | -6.17 | -0.01 |
| 20-40 | 0.017 | 0.014 | 0.0002 | 0.01 | -18.04 | -0.03 |
| 20-60 | 0.008 | 0.007 | 0.0001 | 0.01 | -20.07 | -0.02 |

 

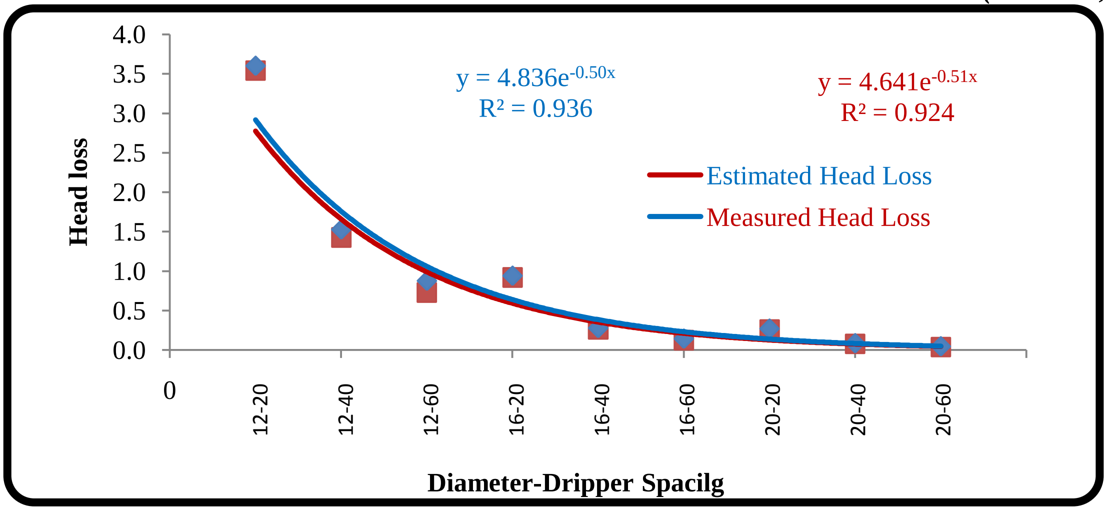


Fig-1(a) Comparison between the $H_{Tm}$ and $H_{Te}$ at 10 m operating pressure (Type-A)

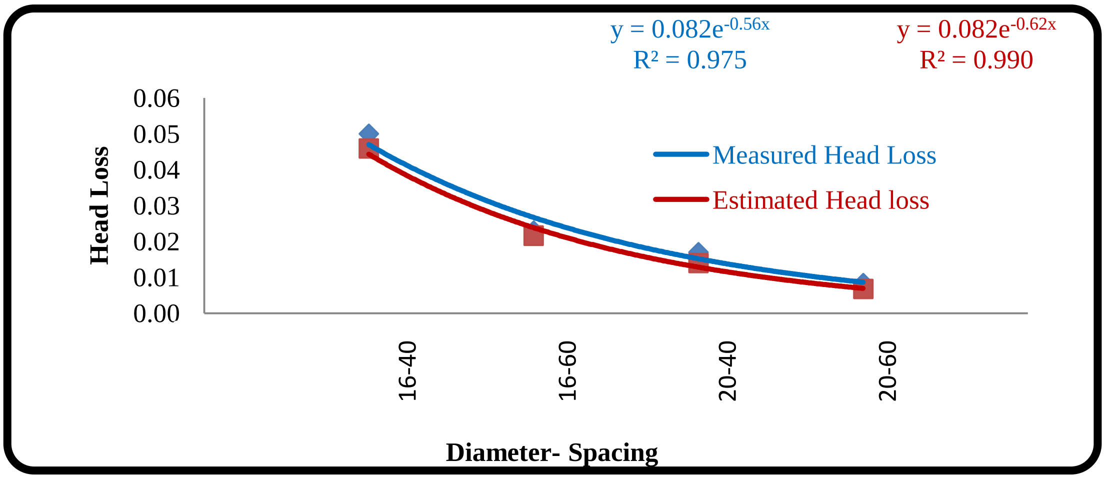


Fig-1(b) Comparison between the $H_{Tm}$ and $H_{Te}$ at 10m operating pressure (Type-B)

Table -II: Comparison between the $H_{tm}$ and $H_{te}$

| For 8m operating pressure | | | | | | |
|---|---|---|---|---|---|---|
| **Diameter-Dripper Spacing (mm-cm)** | **Measured Head loss $H_{Tm}$ (m)** | **Friction loss (Hf), in m** | **Total local loss along lateral, HL in m** | **Estimated head loss $H_{Te}$ (m)** | **$(H_{Te}-H_{Tm})/H_{Tm}$ %** | **$(H_{Te} - H_{Tm})/P$ %** |
| ONLINE LATERALS **TYPE-A** | | | | | | |
| 12-20 | 2.853 | 2.704 | 0.0687 | 2.772 | -2.83 | -1.01 |
| 12-40 | 1.214 | 1.129 | 0.0239 | 1.153 | -5.00 | -0.76 |
| 12-60 | 0.644 | 0.554 | 0.0107 | 0.565 | -12.25 | -0.99 |
| 16-20 | 0.773 | 0.711 | 0.0106 | 0.722 | -6.60 | -0.64 |
| 16-40 | 0.253 | 0.208 | 0.0025 | 0.211 | -16.61 | -0.53 |
| 16-60 | 0.132 | 0.102 | 0.0007 | 0.102 | -22.47 | -0.37 |
| 20-20 | 0.222 | 0.210 | 0.0013 | 0.211 | -4.91 | -0.14 |
| 20-40 | 0.070 | 0.063 | 0.0002 | 0.063 | -9.31 | -0.08 |
| 20-60 | 0.035 | 0.030 | 0.0000 | 0.030 | -14.01 | -0.06 |

 

| INLINE LATERALS **TYPE-B** | | | | | | |
|---|---|---|---|---|---|---|
| 16-40 | 0.049 | 0.045 | 0.0010 | 0.046 | -5.62 | -0.03 |
| 16-60 | 0.021 | 0.021 | 0.0006 | 0.021 | 3.45 | 0.01 |
| 20-40 | 0.016 | 0.014 | 0.0002 | 0.013 | -13.02 | -0.03 |
| 20-60 | 0.008 | 0.007 | 0.0001 | 0.006 | -19.21 | -0.02 |

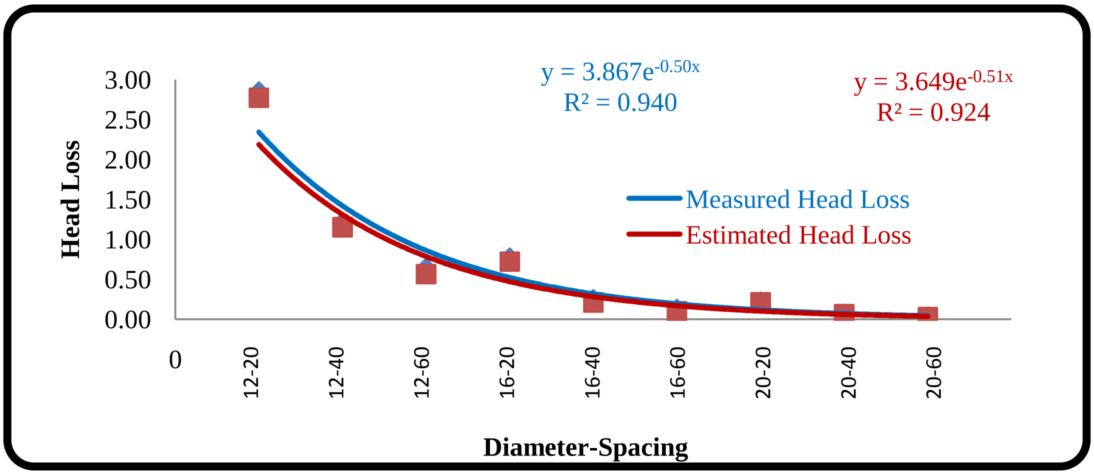


Fig-2(a) Comparison between the $H_{Tm}$ and $H_{Te}$ at 8 m operating pressure (Type-A)

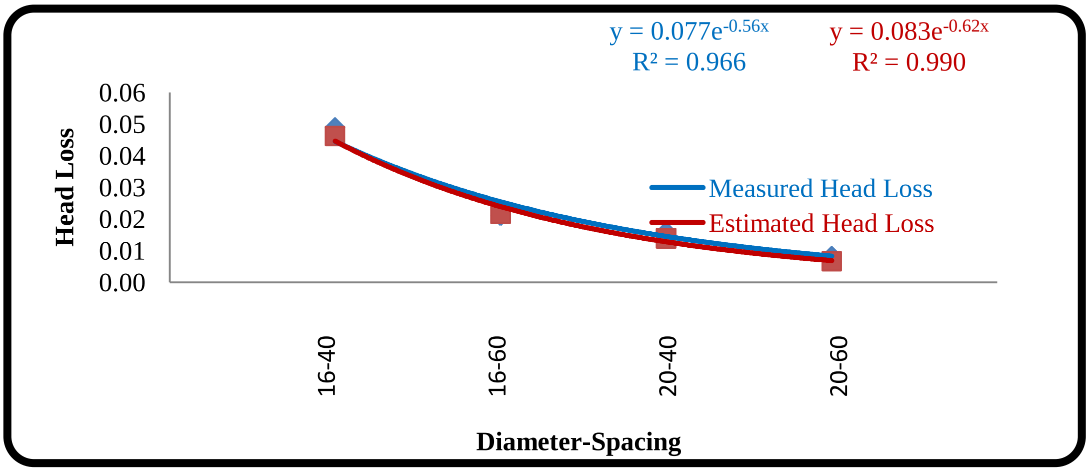


Fig-2(b) Comparison between the $H_{Tm}$ and $H_{Te}$ at 8 m operating pressure (Type-B)

TABLE -III: Comparison between the $H_{tm}$ and $H_{te}$

| **For 8m operating pressure** | | | | | | |
|---|---|---|---|---|---|---|
| **Diameter-Dripper Spacing (mm-cm)** | **Measured Head loss $H_{Tm}$ (m)** | **Friction loss (Hf), in m** | **Total local loss along lateral, HL in m** | **Estimated head loss $H_{Te}$ (m)** | **$(H_{Te}-H_{Tm})/H_{Tm}$ %** | **$(H_{Te} - H_{Tm})/P$ %** |
| ONLINE LATERALS **TYPE-A** | | | | | | |
| 12-20 | 2.0710 | 2.012 | 0.0510 | 2.063 | -0.38 | -0.13 |
| 12-40 | 0.9200 | 0.837 | 0.0177 | 0.855 | -7.11 | -1.09 |
| 12-60 | 0.5180 | 0.425 | 0.0076 | 0.433 | -16.42 | -1.42 |
| 16-20 | 0.6110 | 0.537 | 0.0077 | 0.545 | -10.82 | -1.10 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 16-40 | 0.1980 | 0.158 | 0.0021 | 0.160 | -18.99 | -0.63 |
| 16-60 | 0.0950 | 0.076 | 0.0006 | 0.076 | -19.75 | -0.31 |
| 20-20 | 0.1740 | 0.159 | 0.0011 | 0.160 | -7.97 | -0.23 |
| 20-40 | 0.0560 | 0.048 | 0.0002 | 0.048 | -14.71 | -0.14 |
| 20-60 | 0.0290 | 0.024 | 0.0000 | 0.024 | -16.90 | -0.08 |
| INLINE LATERALS **TYPE-B** | | | | | | |
| 16-40 | 0.0490 | 0.045 | 0.0012 | 0.0467 | -4.61 | -0.04 |
| 16-60 | 0.0240 | 0.021 | 0.0007 | 0.0219 | -8.71 | -0.03 |
| 20-40 | 0.0180 | 0.014 | 0.0002 | 0.0139 | -22.61 | -0.07 |
| 20-60 | 0.0090 | 0.007 | 0.0001 | 0.0067 | -25.45 | -0.04 |

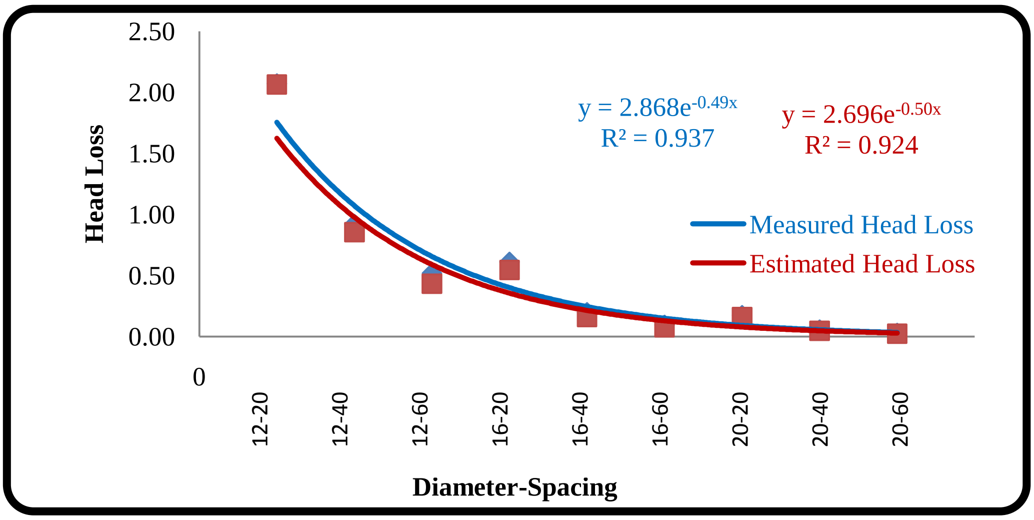


Fig-2(b) Comparison between the $H_{Tm}$ and $H_{Te}$ at 6 m operating pressure (Type-B)

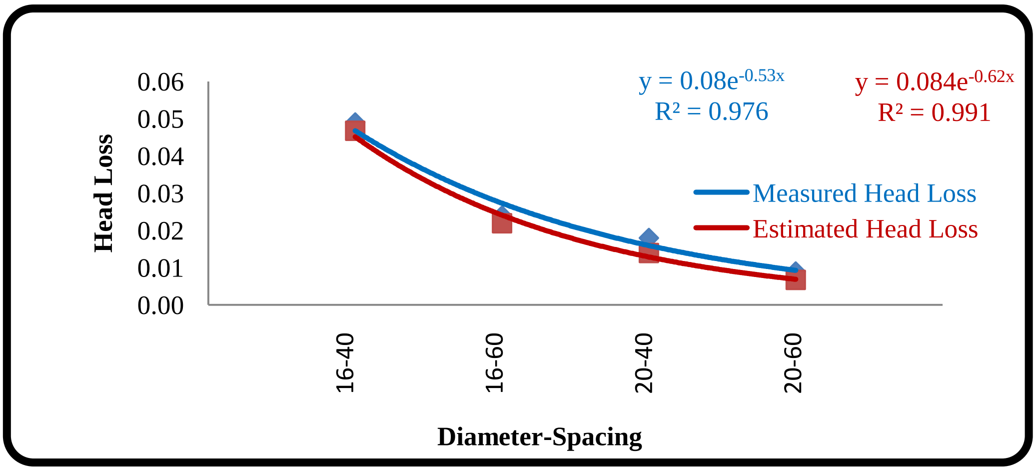


Fig-2(b) Comparison between the $H_{Tm}$ and $H_{Te}$ at 6 m operating pressure (Type-B)

## IV. CONCLUSIONS

The experimental study for evaluating local head loss due to non pressure compensating online emitters in drip irrigation lateral (Type-A) and pressure compensating inline emitters in drip irrigation lateral (Type-B) is carried out. The analysis is carried out with different diameters of laterals, with different emitter spacing and with three different operating heads. The following are the main conclusions of this study.

1) The experimental and evaluated head loss study carried out on Type-A and Type-B laterals with different diameters, operating pressures and with different emitter spacing shows that the head loss is a function of diameter and spacing of emitters. There is an inverse relationship of head loss with diameter of lateral and emitter spacing. The energy loss is higher as the diameter decreases and as the emitter spacing reduces and vice versa.

 

2) The total head loss has been calculated at different operating pressures which show that the amount of total head loss reduces as the operating pressures reduce, thus there is a direct relationship between total head loss and operating pressure.
3) The comparison between estimated and measured head loss for Type-A and Type-B laterals shows that the head loss verses diameter/spacing is around best fit parabola with satisfactory comparison of the estimated and measured head loss. The difference between estimated and measured head loss expressed as a percentage of measured head loss at above mentioned pressure heads were found to be in range between -1.6% to -20.0%, -2.8% to -22.5%, -0.4% to -25.5 respectively. The minimum variation is found to be very less and it is quite acceptable. The study reveals that the estimated total head loss (HTe) is reasonably accurate and can be used for estimation purpose. It is also seen that the lesser the emitter spacing along the length of the lateral, smaller is the error ( between estimated and measured ) in head loss and vice versa.
4) It can be concluded that the estimated total head loss and measured total head loss values are nearly the same. So estimation of total head loss by the equations adopted is reliable and these equations can be used directly for various diameters and dripper spacing in the design of drip irrigation laterals.

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