ABSTRACT

The gravity-fed drip irrigation was fabricated using local and market available materials. The test crops were bottle gourd, bitter gourd and cucumber, grown in specially dugout pits, filled with medium textured soil mixed with manures, fertilizers. The CROPWAT model was used to estimate the ET of various vegetables for scheduling irrigation. Systems hydraulic performance was evaluated by measuring discharge variation among the different emitters, estimating friction head losses in different components. The frictional head loss in the lateral was found to be 0.2640 cm cumulatively. Whereas the frictional head loss of emitters was found to be 67.73 cm, the frictional head losses in the fitting were found out to be 6.995 cm. Total head requirement of the system included the head required at the farthest emitter for operation and the frictional losses in the bend, control valve and filter as 2.3 m. Among the vegetable, the bottle gourd resulted in significantly higher average yields as compared to other vegetables. Bottle gourd produced highest yield under drip irrigation (290.9 q ha\(^{-1}\)), closely followed by the yield under basin irrigation (229.2q ha\(^{-1}\)). In this way the locally fabricated micro drip irrigation system was found significantly superior as compared to the basin irrigation.

Key words: Gravity fed drip irrigation system, Frictional loss, Basin irrigation crop yield.
Tree plantation model:
The study area comprised of four tree species *i.e.* *Gmelina arborea* (Khamar), *Dalbergia sissoo* (Sissoo), *Albizia lebbeck* (Kalasiris), *Emblica officinalis* (Aomla) etc. with different spacing to increase the biomass production and organic matter in the soil. Vegetable crops were grown in between the tree as an inter-crop with additional remuneration in dugout soil pits filled with medium textured soil mixed with farm yard manures and fertilizer. Gravity based drip irrigation, basin irrigation were applied for saving of young plantation especially during summer season.

Design of micro drip irrigation system:
The manifold and its lateral were designed and operated as a single manifold system, the micro drip irrigation system, which was controlled by a single valve and inline filter. The details of various design parameters were worked out as fallows.

Area : 28 x 26 = 672 (nearby flat)
Water source : Farm pond, Tank - HDPE 750 liters capacity, positioned on adjustable platform (height-1.5-2.5m)
Test crops : Bottle gourd, Cucumber and Bitter gourd
Climate : Semi -humid
Soil type : In general-Bhata land (waste land) – sandy loam
Pits – Clay loam
Infiltration rate: In General -Average 18 mm h⁻¹ and in Pits - 10 mm h⁻¹
ET crop peak : 8.3 mm day⁻¹
Ground water contribution: Nil
Effective root zone depth D : 0.50 m
Field capacity of soil FC : 19.4 per cent by weight
Permanent wilting point PWP: 8.48 per cent by weight
Bulk density of Soil, W : 1.78 g cm⁻³
Critical point for MDIS, CP : 0.85 (allowable moisture depletion 15%)
Application point for MDIS, CP : 0.85 (allowable moisture depletion 15%)
Emitter efficiency, Eₑ : 90 per cent
Lateral spacing, S₁ : 4 m
Emitter spacing, Sₑ : 1 m
From the above mentioned field data, the various parameters of drip irrigation design were worked out. Stepwise procedure followed was as follows:

*Step 1*: Net depth of water to be applied in one irrigation

\[
d_{\text{net}} = \left(\frac{\text{FC} - \text{PWP}}{100}\right) \times W \times \left(1 - \text{CP}\right) \times D \times 100 \quad \text{(1)}
\]

\[
= \left(\frac{19.4 - 8.48}{100}\right) \times 1.78 \times \left(1 - 0.85\right) \times 0.5 \times 100 \quad \text{(2)}
\]

*Step 2*: Gross depth of water to be applied in single irrigation

\[
d_{\text{gross}} = \frac{d_{\text{net}}}{Eₐ} = \frac{11.66}{0.9} = 12.95 \text{mm} = 0.01295 \text{m} \quad \text{(3)}
\]

*Step 3*: Irrigation interval, days.

\[
\text{Irrigation interval} = \frac{d_{\text{gross}}}{\text{ET crop}} = \frac{12.95}{11.5} = 1 \text{ day}
\]

*Step 4*: System capacities:
It was assumed that 672 m² area will be irrigated in 2 hours in one day and the fraction of the total area wetted = 0.1

Main:
Main pipe is immediately linked to the sub-main within 1.5 m distance.

Sub-main:
\[
A = 672 \times 0.16 = 107.52 \text{ m}^2
\]

Capacity (flow rate) \( q = \frac{0.01295 \times 107.52}{7200} = 696.192 \text{ L h}^{-1} \)

Lateral:
Length of each lateral: 26 m, Number of laterals: 7

\[
Q_{\text{lat}} \text{ capacity of each lateral} = \frac{696.192}{7} = 99.45 \text{ L h}^{-1}
\]

Emitter discharge:
Capacity of the emitter is its discharge per plant

\[
\text{Emitter discharge} = \frac{d_{\text{gross}} \times A_1}{t} = 1.1655
\]

Since one lateral cover two plant rows, each emitter was provided with two micro tube, hence discharge per micro tube is 0.58275 Lh⁻¹

Daily water requirement:
The daily water requirement of vegetable grown under drip irrigation method was estimated by using the formula

\[
\text{Volume of water required daily} = \frac{\text{daily water requirement} \times \text{water efficiency}}{\text{water efficiency}}
\]

Volume of water required per plant per day was 2.988 L per day

**Step 5:** Frictional head losses in different components

- **Main:** Pressure drop due to friction for main, 1.5 m length can be calculated by using the formula suggested by Williams and Hazans as given below

\[
H_f = 15.27 \times Q^{0.45} D^{-4.871}
\]

where \( H_f \) = Friction losses, m
\( Q \) = Total pipe flow, 0.19338 lps
\( D \) = Inside diameter of the pipe, 5.74 cm
\( L \) = Length of pipe, 1.5 m

Total friction losses along the length of main was found 0.022 cm

**Sub-main:**

The main was attached to the sub-main which had total length of 28 m. There were 7 laterals attached to the sub-main. The frictional head losses in different sections of the sub-main were worked out and then these were summed up to get total head losses. Frictional head loss in the \( n^{th} \) section was worked out as follows:

\[
F_n = \frac{f_n LV^2}{2gD}
\]

where, \( F_n \) is the head loss due to friction in \( n^{th} \) section of the line, m
\( f_n \) is the friction factor in \( n^{th} \) section of line
\( L \) is the length of \( n^{th} \) section of line, m
\( g \) is the acceleration due to gravity, 9.81 m s\(^{-2}\)
\( D \) is the inside diameter of the sub-main, m

Friction factor depends upon the Reynolds number. Total friction losses in the sub main section will double the cumulative friction of one part of sub main.

**Laterals:**

The flow passing through \( n^{th} \) section of lateral was worked out by equation based on the Reynolds number. Where the Kinematics viscosity of water was considered as 10\(^{-6}\) m\(^2\) s\(^{-1}\). The flow was considered to be laminar if Reynolds number was less than 2000 and turbulent if it was greater than 10000.

In case of laminar flow the friction factor was worked out by

\[
f_n = \frac{64}{Re}
\]

In the case of turbulent flow the friction factor was worked out by

\[
f_n = \frac{0.316}{Re^{0.25}}
\]

In the present study, the friction factor was calculated for each section of the line based upon the flow characteristics evaluated through \( Re \). The cumulative friction head loss in lateral line and sub main line with multiple outlets and for varied spacing of emitters and lateral line were obtained by using the above said procedure.

**Emitters:**

The frictional head loss in the emitters (in cm) was calculated by Darcy-Weisbach’s formula rearranged as follows:

\[
H_f = \frac{L_t f q^2}{15.68 \times D^5}
\]

where, \( L_t \) is length of micro tube in m, \( D \) is inner diameter of micro tube in mm, \( q \) is the discharge of emitters in L h\(^{-1}\), \( f \) is the friction factor calculated for laminar flow as 64 / \( Re \)

**Fittings:**

Friction head loss in fitting was calculated in terms of knowing equivalent length of main and by using standard tables. It was shown in Table 1 and after that by summing all these friction loss, total friction in fitting is 6.995 cm

**Step 7:** Total head requirement of the system: Total head requirement of the system included the head required at the farthest emitter for operation and the frictional losses in the bend, control valve and filter etc.

\[
H_{sys} = \text{Head required for operation} + \text{frictional losses (pipes + fittings + emitters)}
\]

**Discharge - head relationship:**

The flow rates of emitters for a constant head at each node were measured. This was done by collecting the amount of water in a measuring flask with a time

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**Table 1: Frictional losses in different component used in fitting**

<table>
<thead>
<tr>
<th>Component</th>
<th>Equivalent length of main Le/d where d = 57.4 mm</th>
<th>Equivalent length of component Le, mm</th>
<th>Friction losses in component cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control valve</td>
<td>3</td>
<td>172.2</td>
<td>0.34</td>
</tr>
<tr>
<td>Filter</td>
<td>40</td>
<td>2296</td>
<td>4.59</td>
</tr>
<tr>
<td>Tee connection</td>
<td>8</td>
<td>459.5</td>
<td>0.9184</td>
</tr>
<tr>
<td>Reducer T-T connection</td>
<td>10</td>
<td>574.0</td>
<td>1.148</td>
</tr>
</tbody>
</table>

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interval of 5 minutes and then converting it to emitter flow rate in L h⁻¹. While taking measurement of emitters it was kept in minds that the head variation should not be much (< 10 cm). Water tank was positioned on adjustable platform; it facilitated the water tank to be positioned at 1.5 m height from the ground level. An attempt was made to study the effect of various heads of water on the discharge of emitters. The water heads were allowed to vary from 1.5-2.5 m.

RESULTS AND DISCUSSION

The judicious use of scarce water resources can be made by water efficient methods such as drip irrigation. The low cost versions of micro irrigation viz. gravity-fed drip irrigation system attempted to fabricate and evaluated at the study site for vegetable production.

Frictional head losses:

The frictional head losses in different components were worked out by using different formulae as given by equations 1.5 to 1.8. The frictional head loss in main was 0.022cm and that of sub-main the cumulative figure was 0.039cm whereas in the lateral was found to 0.2640 cm cumulatively. Total frictional head loss in all seven laterals was found to be 1.848 cm. The frictional head loss of emitters was calculated by equation 1.9 and that was found to be 67.73 cm whereas the frictional head losses in the fitting were found out to be 6.995 cm. As the length of the pipe (sub main, lateral) increased, the cumulative frictional losses in that pipe also increased. Fig. 1 and 2 show the variation in frictional head loss in sub-main and laterals, respectively. The polynomial relationship existed between the cumulative frictional head losses in sub-main and linear relationship for laterals with high value of the coefficient of determination (sub-main: r=0.89, lateral: r=0.99). These figures indicated that with the increase in the section length of the pipe, the cumulative friction head losses increased. Coefficient of uniformity (CU) of the system was determined. It varied from 98.67 to 99.69 per cent in laterals with an overall CU of the system as 99.2 per cent whereas the emission uniformity (EU) was found to vary from 97.93 to 99.22 per cent with an overall system’s EU was worked out to be 98.93 per cent.

Total head requirement of the system:

The total designed head required for the system was worked out. It was found to be 2.3 meters, in which frictional head losses in various components accounted for 33.73 per cent. The remaining 66.26 per cent of the total head was required at the farthest emitter to work. Guled et al. (1997) reported that low-head drip systems operate under pressures of 0.5-2.0 m compared to the 10-15 m water head needed for standard drip irrigation.

Discharge – head relationship:

Head – discharge relationship of micro tubes showing the variation in average discharge values at different pressure heads are depicted in Fig. 3. This relationship was found to be represented by second order polynomial curve. It revealed that the discharge through micro tubes of 2 mm diameter increased with increased head. The same trend was observed at head, middle and tail end of the lateral of 26 m length. But it was noticed that the discharge decreased with increased length of lateral. The following correlation by polynomial function was established between average discharge of micro tubes (Q) in L h⁻¹ and pressure head (H) in m.

\[ Q = -0.002H^2 + 0.021H + 0.5149 \] (1.10)
Crop yields:

On an average the marketable vegetable yields under drip irrigation (194.4 q ha\(^{-1}\)) and were significantly higher by 25.73 as compared to those under basin method of irrigation (156.1 q ha\(^{-1}\)) shown in Table 2. Among crops, bottle gourd resulted in significantly higher yield by 26.9 per cent under gravity fed drip irrigation, respectively over that under basin irrigation (229.2 q ha\(^{-1}\)).

Conclusion:

Tree plantation in waste lands can be made economically attractive and socially acceptable by intercropping of vegetables. In order to promote vegetable production in waste land as well as water scarcity areas gravity-fed drip irrigation can best be used advantageously over basin irrigation.

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REFERENCES


Table 2: Vegetable (Crop) yields in different irrigation (q/ha)

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Replication</th>
<th>Drip irrigation (q/ha)</th>
<th>Basin irrigation (q/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottle gourd</td>
<td>1</td>
<td>298.7</td>
<td>185.8</td>
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<tr>
<td></td>
<td>2</td>
<td>310.5</td>
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<td>3</td>
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<td>193.7</td>
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<td></td>
<td>4</td>
<td>273.0</td>
<td>221.0</td>
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<td></td>
<td>5</td>
<td>290.1</td>
<td>254.2</td>
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<tr>
<td></td>
<td>6</td>
<td>317.0</td>
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<td></td>
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<tr>
<td>Average</td>
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<td>290.9</td>
<td>229.2</td>
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<tr>
<td>Bitter gourd</td>
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<td>154.2</td>
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<td>2</td>
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<td>113.0</td>
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<tr>
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<td>119.25</td>
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<td>Cucumber</td>
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<td>123.7</td>
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<td>123.0</td>
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<td>137.0</td>
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<tr>
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<tr>
<td>Overall average</td>
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<td>194.4</td>
<td>156.1</td>
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