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Standardization of Gravity-Fed Low Head Drip Irrigation System under Variable Operational Head for Small Farms

Rigve* • Anil Bhardwaj • Sanjay Satpute • Jagmeet Singh • Sunil Garg

Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana

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ABSTRACT

A study was conducted to standardize the gravity fed low head drip irrigation system (LHDIS) under variable operational head of 3.0 m to 0.5 m. The results indicate that average emitter discharge as well as emission uniformity (EU) of the system increases with increase in head, decrease in lateral length and decrease in number of laterals and vice-versa. The average emitter discharge was observed to be maximum (3.76 l/h) under operating head of 3 m with 15 m length and 4 laterals and was minimum (0.31 l/h) when head decreased to 0.5 m and length and number of laterals increased to 30 m and 10 laterals, respectively. At 3 m and 2.5 m heads, 6 lateral lines each of 30 m length, 8 laterals each of 25 m length and 10 laterals of 20 m and 15 m length provide fair uniformity of water application through LHDIS with EU>70%. However, to obtain excellent uniformity (EU>90%) only 4 number of laterals each of 20 m or 15 m length can be used under the operating head of 3 m. Also same number of laterals can be used at 2.5 m and 2.0 m heads when length of the lateral lines is reduced to 15 m, to obtain excellent uniformity. Keeping in view the practical difficulty in creating higher operating head (>3.0 m), one has to compromise between the EU of the system to be achieved and the size of the system in terms of the length and number of lateral lines to be used in the system.

1. Introduction

Irrigated agriculture remains the largest user of water globally accounting for more than 70% of water usage throughout the world and 90% of water usage in the developing countries. Also, a remarkable amount of energy is consumed by irrigation systems in contrast to other operations, as indicated by the energy analysis of agricultural operations (Topak *et al.,* 2005). Consequently, it is necessary to utilize scarce irrigation water efficiently and judiciously which is also important from the point of view of sustainability of agriculture (Alam and Kumar 2001). One of the ways to enhance water use efficiency is to apply water through modern methods of irrigation, particularly the drip system having efficiency of more than 90% against around 40% of surface methods of irrigation.

Based on the operating pressure, drip irrigation systems are generally of two types: gravity-fed low head drip irrigation system (LHDIS) and high head drip irrigation system (HHDIS). In hilly areas, the feasible pressure head between 0.5-3.0 m to operate the LHDIS is naturally available between the terraced fields or can be obtained utilizing an overhead tank without using a pumping unit. In contrast, the HHDIS require a pumping unit to build up a high pressure of 15 m or more necessitating the use of electricity and hence is comparatively costly for small farmers. Also, often it is impractical to have electric power available in the remote locations to operate a pumping unit. In India, majority of farmers are small and marginal and in general economically weak, particularly in hilly areas. The HHDIS being power intensive and costly is beyond their economic capacity. The LHDIS that is gravity-fed drip irrigation system requires neither any

*Corresponding author: rgvkshp1@gmail.com

pumping equipment nor electric power unit to drive the pump. It makes this system energy as well as cost efficient in contrast to HHDIS. It not only increases the productivity and income of the small farmers but also conserves the rare and valuable water resource of the country. However, these low head drip irrigation systems (LHDIS) have not been yet standardized. Various technical aspects concerning drip irrigation systems' design have been examined thoroughly by Bucks and Nakayama (1986), and Keller and Bliesner (1990). Wu *et al.* (2010) developed a design procedure for a single-manifold subunit. Wu (1997) evaluated gravity fed drip irrigation systems analogous to the related effects of emitter manufacturing variation, grouping of emitters, emitter plugging and hydraulic design. According to Herath and Gunathilake (2010), increase in inlet pressure head indirectly limits the maximum lateral length. Zhang *et al.* (2011) studied the hydraulic performance of three different makes of commercially available in-line drip tapes/emitters in China under working heads ranging from 0.2 to 10 m in the laboratory. All the emitters were found to be suitable for LHDIS, but the values of coefficient of manufacturing variation and the emitter discharge exponent were sensitive to changes in working head levels of 1.0 or less.

The emission uniformity (EU) of a drip irrigation system is an important parameter related to uniform application of water throughout the field. The discrepancy of emitter discharge along a lateral line depends upon the inlet pressure, emitter spacing, the total flow rate and the total length. This leads to a problem in design while selecting the right combination of pressure, number and length of lateral lines so as to attain an adequate uniform irrigation pattern with high EU (Wu and Gitlin 1974; Wu *et al.* 2010). Zhu *et al.* (2009) developed drip lateral design based on EU and topography variations. The EU usually improves with increasing heads up to 3 m after which uniformity reduces a little. In laboratory experiments, EU does not vary critically with 0.5 m change in head. The EU falls suddenly and reduces linearly with rise in sub-main slopes (Ella *et al.,* 2008). Hence keeping in view the above aspects, present study was planned with the objective to standardize the gravity fed LHDIS based on EU having different combinations of number and lengths of lateral lines to be used under different operating heads.

2. Materials and Methods

The field experiment without crop was carried out at the research farm of Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana, located at an altitude of 247 meters above sea level during the year 2015-16.

2.1 The LHDIS Components, Layout and Installation

The LHDIS was installed in 40 m long and 25 m wide field. In low head drip irrigation, water is applied frequently at low rates from a low pressure delivery system and consists of a storage tank, stand, mainline, valves, tubing adapters and fittings, drip tubing, emitters and end caps. These components are divided into four categories: Storage zone components, Control zone components, Distribution components, Emission devices and other accessories. The storage zone components includes source of water in form of plastic storage tank. In the experiment a PVC storage tank of capacity1000 litre was used. The tank was kept on the angle iron stand having variable height above the ground/field to provide the required pressure head varying from 0.5 m to 3.0 m. A 50 mm pipe was connected as outlet of tank and reducer of size 50mm: 38 mm was fitted that reduced the size of pipe of 50 mm to 38 mm. Then a Tee joint was provided to take off supply for water to level indicator on which reducer reduced the size of pipe from 38 mm to 12 mm. The control zone components control the system operation. The mainline valve was the closest component to the water source tank. It was a 38 mm ball valve to manually open and close water flow to the whole distribution system. Lateral valves were provided in the beginning of the length of lateral to open and close water flow to the individual lateral. It was a 16 mm valve fixed on each lateral. The distribution components delivered water reliably, safely and efficiently to each emitter outlet. It included main pipeline that deliver water from water source tank to sub-main pipeline. In this study rigid 50 mm PVC pipeline was used for this purpose. Sub-main pipeline delivers the water from the main pipeline to lateral lines. The PVC pipe of diameter 38 mm was used as sub-main. Lateral lines distributed water uniformly along their length by means of dripper also called emitters fitted on them at regular spacing. Black polyethylene tubes each of diameter 16 mm have been fitted as laterals in the system. The black color prevents avoid algae growth inside the pipe and minimize the damaging effect of ultraviolet radiation. These laterals were connected to the sub-main. The spacing between the laterals was kept as 1.2 m. Tube Fittings are plastic connectors that attach the drip tubing to other tubes and to the rest of the drip system. Grommet and take off were used to connect the lateral to sub-main. A hole was punched with hand drill in sub-main. Grommet was fixed into the hole on sub-main. Take off was pressed into grommet with take-off punch. Grommet acts as a seal. Reducers were used to connect the pipes of different sizes. A 50 mm to 38 mm reducer was used between the water tank and mainline control valve. A 38 mm to 12 mm reducer was used to connect flexible pipe with mainline Tee joint. The emission devices or emitters control the rate of application of water to the plants in the field.

Figure 1. A view of the installed low head drip irrigation system and measurement of emitter discharge.

In this study each emitter of 4 l/h flow rating connected through micro-tube of length 30 cm were used and fitted at a spacing of 30 cm on each lateral. *Other accessories* include end plugs provided at the end of sub-main to close the sub-main ends, end caps at the end of each drip tubing/laterals that help in flushing out the drip tubing periodically to avoid choking. Water level indicator indicates the level of water in the tank and the head of water at which LHDIS operates. A 3.5 m long angle iron with marking scale was used for this purpose. Transparent flexible pipe taken from the mainline near to water tank was fitted along the scaled height of angle iron to give the level of water in the tank. A view of the LHDIS installed in the field is shown in Figure 1a.

2.2 LHDIS Operation and Data Collection

Constant head of water was maintained in the tank by regulating the supply of water to tank through control valve. System was allowed to run for sometimes, so that the system is free from any foreign particle and air. The head was varied as 3 m, 2.5 m, 2m, 1.5 m, 1 m and 0.5 m. At particular head, lateral lengths were varied as 30 m, 25 m, 20 m and 15 m. For particular head and lateral length, number of laterals was varied as 10, 8, 6 and 4. The1^{st},$1/3^{rd}$, $2/3^{rd}$ and the last emitters were selected in each lateral length to determine the variation of discharge along the length of lateral under each treatment. Emitter discharge for each treatment or combination of operating head, length and number of laterals was measured volumetrically by running the system for 5 minutes. The discharge of each emitter was calculated by dividing the volume of water collected in the cup/bowl by the time (Figure 1b). The data on emitter discharge collected in the experiment was used to calculate EU of the LHDIS for various treatments.

2.3 Emission uniformity

Emission uniformity (EU) is the measure of uniformity of emitters discharge for all the emitters of drip irrigation system. It is the single most important parameter for evaluating system performance. Uniformity of 100% means that the whole parcel has received the exact and same amount of irrigation water everywhere. The EU was estimated using the following equation (Merriam and Keller 1978):

$$EU = \frac{q_{25\%}}{q_{avg}} \times 100$$

Where, EU is the percent emission uniformity, $q_{25\%}$ the average flow rate (l/h) of 25% of the emitters with lowest flow rate, and q_{avg} is the average flow rate (l/h) of all sampled emitters.

The emission uniformity (EU) based performance of the LHDIS was evaluated as per Table 1 (Mane *et al.,* 2008, Merriam and Keller 1978) and the optimum number of laterals and their lengths have been determined accordingly for different combinations of operating head.

3. Results and Discussion

In the field, a common index for indicating water application uniformity of a drip system is its emission uniformity (EU). Hence, EU is considered to be one of the key parameters to decide the optimum number of laterals and length of laterals under different operating heads so as to standardize low head drip irrigation system (LHDIS) and to ensure uniform application of water throughout the field.

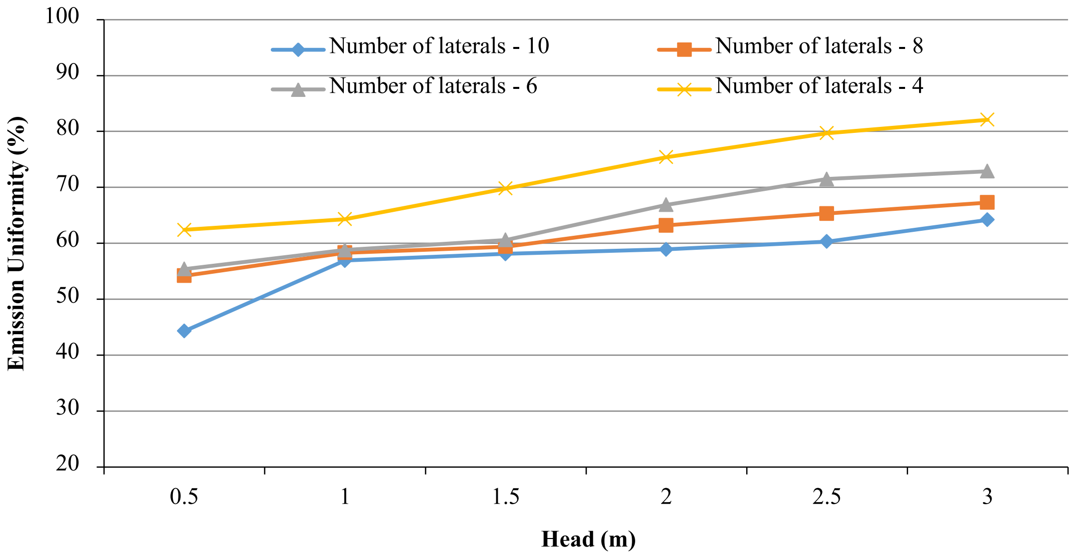

Figure 2. Variation of EU with head and number of laterals for 30 m lateral length

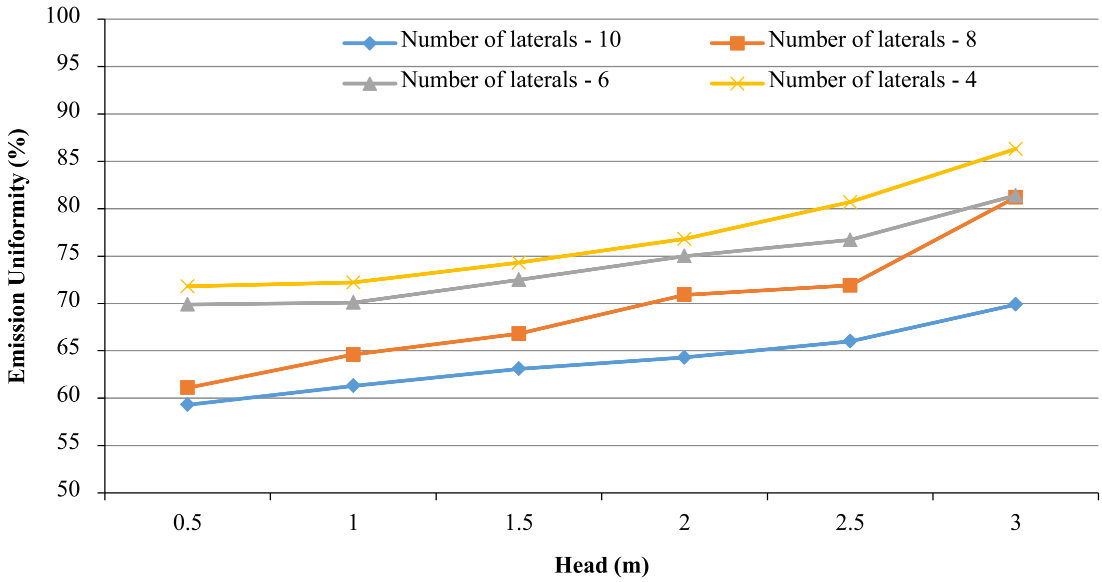

Figure 3. Variation of EU with head and number of laterals for 25 m lateral length

3.1 Variation of average emitter discharge

The average emitter discharge of LHDIS was observed to be maximum (3.76 l/h) when operating head was 3 m and length and number of laterals were minimum *i.e.* 15 m and 4 laterals. With the decrease in head average emitter discharge decreased and with the decrease in length and number of laterals, average emitter discharge increased. The average emitter discharge was minimum (0.31 l/h) when head was minimum *i.e.* 0.5 m and length and number of laterals were maximum *i.e.* 30 m and 10 laterals. At 0.5 m head and 30 m length with 10 laterals the discharge of the last emitter on the laterals was quite low.

In general at each operating head of LHDIS, the average emitter discharge was highest when length and the number of laterals were minimum and it was lowest when length and number of laterals were maximum.

3.2 Variation of EU with Head

The LHDIS was operated in the field at 3 m, 2.5 m, 2 m, 1.5 m, 1.0 m and 0.5 m head with 30 m, 25m, 20 m and 15 m lateral length and 10, 8, 6 and 4 laterals. Based on the emitter discharge under different combinations of head, length and number of lateral lines the values of EU were calculated and has been discussed in the following sub-heads.

3.2.1 At 3 m head

At 3 m head EU of the LHDIS ranged from 64.2% to 93.5%. At 30 m length, 6 and 4 number of laterals provided fair and good uniformity with EU of 72.9% and 82.1%, respectively. For 25 m lateral length, 8, 6 and 4 laterals provided good uniformity with EU of 81.2%, 81.4% and 86.3%, respectively. For 20 m length, 10 laterals provided fair uniformity with EU of 72.8%, 8 and 6 laterals provided good uniformity with EU of 82.9% and 84.2%, respectively, and 4 laterals provided excellent uniformity with EU of 90.6%. For 15 m length, 10 laterals provided fair uniformity with EU 78.4%, 8 and 6 laterals provided good uniformity with EU 88.4% and 89.6%, and 4 laterals provided excellent uniformity with EU of 93.5%. Hence, at 3.0 m operating head, the LHDIS can have 4-6 laterals each of 30 m length, 4-8 laterals of 25 m length and 4-10 laterals with both 20 m length and 15 m length.

3.2.2 At 2.5 m head

The EU varied from 60.3% to 92.6% at an operating head of 2.5 m. At 30 m length, 6 and 4 laterals provided fair uniformity with EU of 71.5% and 79.7%, respectively. For 25 m length, 8 and 6 number of laterals provided fair uniformity with EU of 71.9% and 76.7%, and 4 laterals provided good uniformity with EU of 80.7%. For 20 m length, 10 and 8 laterals provided fair uniformity with EU 70.8% and 72.9%, respectively and 6 and 4 laterals provided good uniformity with EU of 82.2% and 86.7%, respectively. For 15 m length, 10 laterals provided fair uniformity with EU of 75.7%, 8 and 6 laterals provided good uniformity with EU of 83.8% and 89.1%, respectively and 4 laterals provided excellent uniformity with EU 92.6%. Hence, 4-6 laterals can be used each of 30 m length, 4-8 laterals of 25 m length and 4-10 laterals each of 20 m and 15 m length under operating head of 2.5 m.

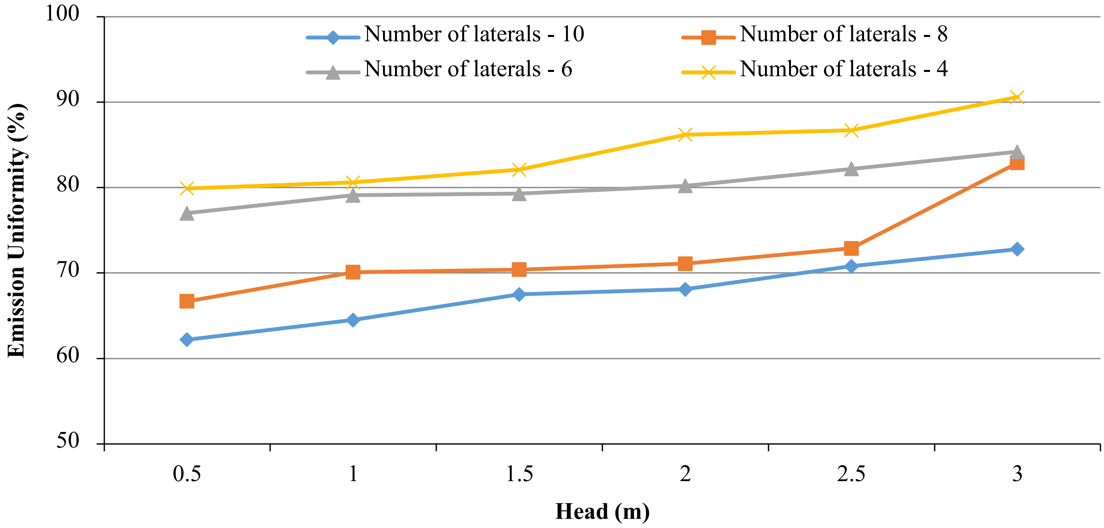

Figure 4. Variation of EU with head and number of laterals for 20 m lateral length.

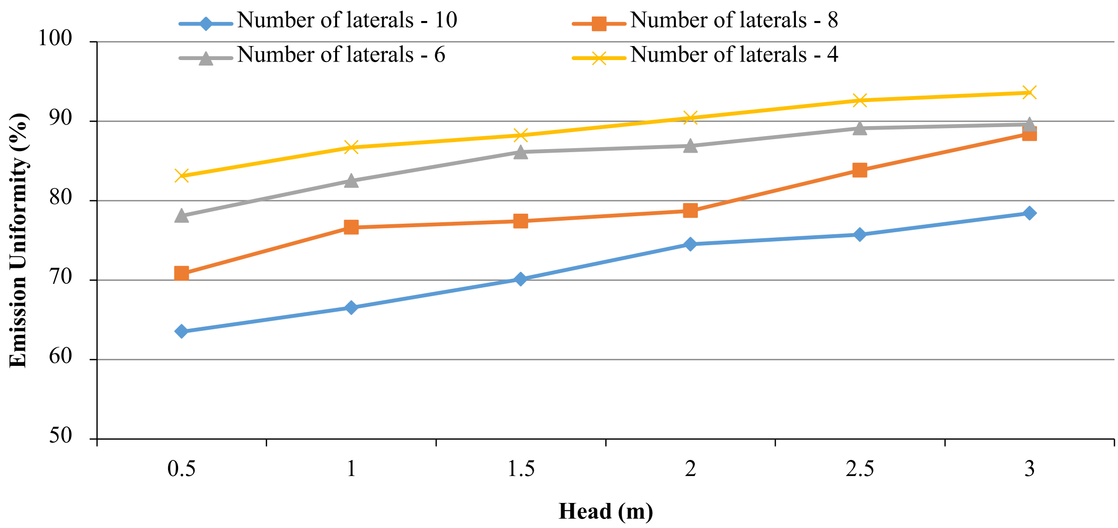

Figure 5. Variation of EU with head and number of laterals for 15 m lateral length

3.2.3 At 2.0 m head

At 2.0 m head, EU ranged from 58.9% to 90.4%. At 30 m length, only 4 laterals provided fair uniformity with EU of 75.4%. For 25 m length, 8, 6 and 4 number of laterals provided good uniformity with EU of 70.9%, 75.0% and 76.8%. For 20 m length, 8 laterals provided fair uniformity with EU of 71.1%, while 6 and 4 laterals provided good uniformity with EU 80.2% and 86.2%, respectively. For 15 m length, 10 and 8 laterals provided fair uniformity with EU 74.5% and 78.7% respectively, 6 laterals provided good uniformity with EU 86.9% and 4 laterals provided excellent uniformity with 90.4%. Hence, 4 laterals each of 30 m length, 4-8 laterals each of 25 m and 20 m length, and 4-10 laterals with 15 m length can be provided under operating head of 2 m.

3.2.4 At 1.5 m head

At 1.5 m head, EU varied from 58.1% to 88.2%. At 25 m length, 6 and 4 laterals provided fair uniformity with EU of 72.5% and 74.3% respectively. For 20 m length, 8and 6 laterals provided fair uniformity with EU of 70.4% and 79.3%, respectively, while 4 laterals provided good uniformity with EU 82.1%. For 15 m length, 10 and 8 number of laterals provided fair uniformity with EU of 70.1% and 77.4%, respectively, and 6 and 4 laterals provided good uniformity with EU of 86.1% and 88.2% respectively. Operating head of 1.5 m did not provide enough pressure to operate drippers uniformly at 30 m length. Hence, 4-6 laterals can be used with 25 m length, 4-8 laterals with 20 m length and 4-10 laterals with 15 m length at an operating head of 1.5 m.

3.2.5 At 1.0 m head

At 1.0 m head, EU varied from 56.9% to 86.1%. For 25 m length, 6 and 4 laterals provided fair uniformity with EU 70.1% and 72.2%, respectively. For 20 m length, 8 and 6 laterals provided fair uniformity with EU 70.1% and 79.1% while 4 laterals provided good uniformity with EU of 80.6%. For 15 m length 8 laterals provided fair uniformity with EU of 76.6% while 6 and 4 laterals provide good uniformity with EU of 87.5% and 86.1%, respectively. Operating head of 1.0 m did not provide enough pressure to operate drippers uniformly at 30 m length. Hence we can use 4-6 laterals each of 25 m length, 4-8 laterals with 20 m or 15 m length.

3.2.6 At 0.5 m head

At 0.5 m head, EU of the LHDIS varied from 44.3% to 83.1%. At 25 m length, only 4 laterals provided fair uniformity with EU of 71.8%. For 20 m length, 6 and 4 laterals provided fair uniformity with EU of 77.0% and 79.9%, respectively. For 15 m length, 8 and 6 laterals provided fair uniformity with EU of 70.8% and 78.1%, while 4 laterals provided good uniformity with EU of 83.1%. Operating head of 0.5 m did not provide enough pressure to operate drippers uniformly at 30 m length. Hence, the system can use 4 laterals each of 25 m length, 4-6 laterals with 20 m length and 4-8 laterals with 15 m length at an operating head of 0.5 m. It is concluded from the above discussion that higher the operating head more number of laterals and length of laterals can be used. Higher EU can be achieved for the LHDIS with 30 m lateral length having 6 and 4 laterals at 3 m head as compared to 2.5 m head and 4 laterals at 2 m head. Lateral length of 25 m length can be used with 8, 6 and 4 laterals to obtain higher emission uniformity at 3 m head as compared to 2.5 m and 2 m head, 6 and 4 laterals at 1.5 m and 1 m head, and 4 laterals with 0.5 m head. Higher uniformity can be obtained with 10, 8, 6 and 4 laterals under 3 m head as compared to 2.5 m head, 8, 6 and 4 laterals at 2 m, 1.5 m and 1 m heads, and 6 and 4 laterals at 0.5 m head, when lateral length of 20 m is used. Similarly, the LHDIS having 15 m length of laterals with 10, 8, 6 and 4 number of laterals resulted in higher uniformity at 3 m head as compared to 2.5 m, 2 m and 1.5 m head, and 8, 6 and 4 laterals at 1.0 m head and 0.5 m head.

Table 1. Drip irrigation system performance based on EU

S. No.	Emission Uniformity	System Performance
1	> 90%	Excellent Uniformity
2	80% - 90%	Good Uniformity
3	70% - 80%	Fair Uniformity
4	< 70%	Poor Uniformity

3.3 Variation of EU with Length of Laterals

3.3.1 For 30 m lateral length

The variation of EU at 30 m lateral length for different heads and number of laterals is shown in Fig. 2. It is evident from the figure that EU of the LHDIS is highest when the number of laterals was kept as 4, and decreases with the increase in number of laterals from 4 to 10. Also EU was lowest at minimum head (0.5 m) and maximum at highest head (3.0 m) irrespective of the number of laterals attached to the system. At 0.5 m head with 10 laterals, a very less amount of water reach the full length particularly in the outermost laterals due to insufficient operating pressure, and because of that EU is very low (44.3%).

Table 2. Maximum number of laterals at different heads (h) and lateral lengths (L) for EU>70%

L \ H	Number of laterals					
	3 m	**2.5 m**	**2 m**	**1.5 m**	**1.0 m**	**0.5 m**
30 m	6	6	4	-----	----	----
25 m	8	8	8	6	6	4
20 m	10	10	8	8	8	6
15 m	10	10	10	10	8	8

3.3.2 For 25 m lateral length

The variation of EU at 25 m length for different heads and number of laterals is shown in Figure 3. For 25 m length of laterals and under 3 m, 2.5 m, 2 m, 1.5 m, 1 m and 0.5 m heads the values of EU for 10 laterals ranged between 69.9% and 59.3%, for 8 laterals between 81.2% and 61.1%, for 6 laterals 81.4% and 69.9%, and for 4 laterals between 86.3% and 71.8%, respectively. The trend in the variation of EU is same with respect to operating head, and number of laterals as in case of 30 m length of laterals.

3.3.3 For 20 m lateral length

The variation of EU of the LHDIS with 20 m length of laterals for different heads and number of laterals is shown in Figure 4. Under the operating heads of 3-0.5 m, the values of EU for 10 laterals varied from 72.8% to 62.2%, for 8 laterals from 82.9% to 66.7%, for 6 laterals from 84.2% to 77.0%, and for 4 laterals from 90.6% to 79.9%, respectively.

3.3.4 For 15 m lateral length

The variation of EU at 15 m length for different heads and number of laterals is shown in Figure 5. For 15 m length of laterals and under 3 m, 2.5 m, 2 m, 1.5 m, 1 m and 0.5 m heads the values of EU for 10 laterals were 78.4%, 75.7%, 74.5%, 70.1%, 66.5% and 63.5%, for 8 laterals were88.4%, 83.8%, 78.7%, 77.4%, 76.6% and 70.8%, for 6 laterals were 89.6%, 89.1%, 86.9%, 86.1%, 82.5% and 78.1%, and for 4 laterals were 93.5%, 92.6%, 90.4%, 88.2%, 86.7% and 83.1%, respectively.

The above trend in data shows that the EU is maximum (93.5%) when the head is maximum (3 m) and length and number of laterals is minimum *i.e.* 15 m and 4 laterals. With the decrease in head, EU decreases while with decrease in length and number of laterals, EU increases. The EU is observed to be minimum (44.3%) when head is minimum (0.5 m) and length and number of laterals are maximum *i.e.* 30 m and 10 laterals, respectively.

3.4 Maximum number and length of laterals in a LHDIS at different operating heads

3.4.1 With EU>70%

The maximum number of laterals and their lengths that can be used for the LHDIS under different operating heads with fair uniformity (EU>70%) are given in Table 2. As is evident from the table, the LHDIS can have maximum 6 numbers of laterals under the operating heads of 3 m and 2.5 m, and 4 numbers of laterals under a head of 2 m head with 30 m length. Maximum of 8, 8, 8, 6, 6 and 4 laterals each of 25 m length can be used in the drip system under 3 m, 2.5 m, 2 m, 1.5 m, 1 m and 0.5 m pressure heads, respectively. When the lateral length is kept as 20 m, maximum 10 laterals can be used with 3 m and 2.5 m heads, and 8 laterals with 2 m, 1.5 m and 1 m heads, and 6 laterals with 0.5 m head, and when the lateral length is 15 m, maximum 10 laterals under 3 m, 2.5 m, 2 m and 1.5 m heads, 8 laterals under 1 m and 0.5 m can be used to achieve fair uniformity of water application through LHDIS.

3.4.1 With EU>80%

The maximum number of laterals and their lengths which can be used for any LHDIS under different operating heads with good uniformity are given in Table 3. As can be seen from table, maximum 4 number of laterals can be used with 3 m head and 30 m length. When lateral length is 25 m, maximum 8 and 4 laterals can be used with 3 m and 2.5 m head. When length of lateral is kept 20 m, maximum 8 laterals can be used with 3 m, 6 laterals with 2.5 m and 2 m, and 4 laterals at 1.5 and 1 m head. With 15 m length maximum 8, 8, 6, 6, 6 and 4 laterals can be used with 3 m, 2.5 m, 2 m, 1.5 m, 1 m and 0.5 m heads, respectively.

3.4.1 With EU>90%

Emission uniformity of 90% or more signifies excellent uniformity of water application in the field through LHDIS. Only 4 number of laterals each of 20 m length can be used under the operating head of 3 m, and same number of laterals can also be used at 2.5 m and 2.0 m heads but with reduced

Table 3. Maximum number of laterals at different heads and lateral lengths for EU>80%

L \ H	Number of laterals					
	3 m	2.5 m	2 m	1.5 m	1.0 m	0.5 m
30 m	4	-----	------	-----	-----	-----
25 m	8	4	-----	-----	----	-----
20 m	8	6	6	4	4	-----
15 m	8	8	6	6	6	4

length of 15 m to obtain excellent uniformity with EU>90%. This shows that higher the operating head, higher would be the EU, thereby more number of lateral lines as well as their length can be used with the LHDIS. For achieving EU≥90%, only 4 laterals each of 20 m length can be used under the operating head of 3 m. On the other hand if EU of 70% is acceptable, 10 laterals of same length can be used. Also, in the field it is very difficult to create operating head greater than 3.0 m. Hence, keeping in view this limitation, one has to compromise between the EU of the system to be achieved and the size of the system in terms of the length and number of lateral lines to be kept in the system. If the system is to be designed and operated under limited water supply/availability, one has to compromise the EU to be obtained and thus can increase the size of the system so as to cover more area per unit of water and accordingly the number and length of lateral lines should be decided.

Conclusions

This study was conducted to standardize the gravity fed LHDIS based on EU having different combinations of number and lengths of lateral lines to be used under different operating heads. The results of the study indicate that average emitter discharge as well as EU of the system increases with increase in head, decrease in lateral length and decrease in number of laterals and vice-versa. At 3 m and 2.5 m heads, 6 lateral lines each of 30 m length, 8 laterals each of 25 m length and 10 laterals of 20 m and 15 m length provide fair uniformity of water application through LHDIS with EU>70%. However to obtain excellent uniformity (EU>90%) only 4 number of laterals each of 20 m or 15 m length can be used under the operating head of 3 m. Also same number of laterals can be used at 2.5 m and 2.0 m heads when length of the lateral lines is reduced to 15 m, to obtain excellent uniformity. Keeping in view the practical difficulty in creating higher operating head (>3.0 m), one has to compromise between the EU of the system to be achieved and the size of the system in terms of the length and number of lateral lines to be used in the system. If the system is to be designed and operated under limited water supply/availability, one has to compromise the EU to be obtained and thus can increase the size of the system so as to cover more area per unit of water and accordingly the number and length of lateral lines should be decided. However if water supply is not limited, one can go for higher EU and smaller size of the LHDIS.

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