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Design chart development for drip irrigation system lateral lines

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Abstract
Drip irrigation is the water application technique that is most effective. Water is applied to the root area of the plant in the drip irrigation. The aim of this research was to create a graphical method for developing lateral pipelines of drip irrigation system based on the allowable pressure head variation. Design equations were modified and arranged for coaxial plotting to develop the design charts in the required form. The lateral lines were intended to read the information as lateral length, emitter spacing, average emitter discharge, diameter, average operating head and slope on separate axes by creating the design graphs; and to obtain values of friction head loss and pressure variation as output outcomes. The design chart created can be used readily and precisely to design lateral line for any specified field information values at upward slopes. Instead of fixing a specific value, the design chart can be used to consider any value of pressure variation in lateral lines. Based on the development methodology, the design charts can be expanded further according to designers and manufacturers.

Keywords: Design chart development, drip irrigation system, lateral lines

Introduction

India is basically a semi-arid country with limited surface and sub-surface water sources. Due to increasing population and rapid industrialization the demand of water is increasing considerably. The agriculture sector is the major user of water as it uses about 80% of the available fresh water. The dominant methods of irrigation from these early times have been surface or gravity and sprinkler irrigation. The application of irrigation water to the crop can be done by flooding the water on the field surface and applying in the beneath the soil surface using high pressure or low pressure mechanisms. It is difficult to give the required quantity of water regularly to the root zone using surface irrigation and yields are often less than optimum. But in drip irrigation water is given daily and hence moisture equal to field capacity of the plant is always available. The irrigation water needs to be measured and regulated time wise and quantity wise. There is an urgent need for flexible irrigation water deliveries in order to meet efficiently the changing demands of irrigation water created by farm management practices, variable soil intake rate, and crop evapotranspiration. Drip irrigation is one of the latest methods of irrigation, which is becoming increasingly popular in areas having water scarcity and moderate salt problems.

Design of drip irrigation system depends on several parameters including topography, soil type, crop to be irrigated, weather conditions, technological and financial resources. The proper design of a drip irrigation system could reduce irrigation water losses (Keller and Bliesner 1990) [16]. The drip irrigation system is one in which all emitters deliver the same volume of water in a given irrigation time so that each plant would receive the same quantity of water in an irrigation period. The flow will be affected by the variation in water pressure and manufacturing characteristics. The emitter flow variation caused by water pressure variation in trickle irrigation system can be controlled by hydraulic design. It is necessary that the flow rates through the system should be uniform even though the pressure is not uniform (Solomon and Keller, 1978) [22].

The proper design of lateral of drip irrigation system will be helpful in increasing the yield with uniformity distribution of water at a feasible pressure variation. The design of drip irrigation system involves the design of lateral line, according to field conditions. The pressure variation in lateral line is a deciding factor for the pipe sizes. The pressure variation depends on the length, diameter, average operating pressure head and slope. The variation of discharge from emitters along a lateral lines creates a design problem to select the right combination of pipe sizes in order to achieve an acceptable uniformity distribution of irrigation. The limit of pressure variation is decided according to the discharge exponent of an emitter. Thus, the right selection of combination of emitters and pipe sizes is important not only from uniform distribution point of view, but also from minimizing the overall cost of the drip irrigation system. Several researchers have developed graphical, analytical and computerized methods of designing the lateral lines of drip irrigation system. However, the graphical methods are still being preferred due to easy availability and use especially by non-technical persons who are mostly involved in installation/popularization of the system.

Materials and Methods

The design equations have been presented and modified to develop design charts for different field and manufactures data. The methodology of developing and the techniques of using the design charts have been presented.

Hydraulics of Drip Irrigation System

The hydraulic design of a drip irrigation systems based on the uniformity of all emitters flow in lateral and submain units. Since the emitter flow is directly affected by the pressure at the emitter, the pressure variation is an indication of uniformity in the drip irrigation system and can be used as design criteria for hydraulic design. The goal of uniform irrigation is to ensure, as much as feasible, that each portion of the field receives the same amount of water, as well as nutrients and chemicals. As water flow through the lateral tubing, there is friction between the wall of the tubing, and the water particles.

The magnitude of pressure loss in a pipeline depends on flow rate, pipe diameter, roughness coefficient, changes in elevation, and the lateral length. When a pipelines is placed upslope, the emitter flow rate decreases most rapidly. This is due to the combined influence of elevation and friction loss. The goal of hydraulics of drip irrigation system is to move water from the source to irrigation field and the root zone of the irrigated plants. Thus, the design must include the hydraulic and energy analyses of the system for proper sizing of component and to ensure uniform distribution of water. A drip irrigation system can be designed hydraulically to maintain emitter flow uniformity within 10% or 20% emitter flow variations (Wu and Gitlin, 1974) [23]. The hydraulics related to meet the above requirements of drip irrigation system is presented in the following sections.

Emitter/ Drippers

Drip irrigation emitters are the small water dispensing devices that are designed to dissipate pressure and constantly discharge a small, uniform flow of water. The flow rate through the emitter is controlled by the hydraulic pressure at the emitter and flow path dimensions of the emitter.

Allowable pressure variation

The pressure variation in the lateral pipeline of drip irrigation system depends on the elevation head, friction loss and average operating head. For proper designing of drip irrigation system, the pressure variation should be less than 20% in the lateral and submain line. The desirable pressure variation should be less than 20% or emitter flow variation less than 10%. The acceptable pressure variation should be from 20 – 40% or emitter flow variation about 10 - 20% (Wu and Gitlin 1974 and 1975) [23]. The pressure variation in the pipeline can be calculated as:

(a) For lateral line the pressure variation can be calculated by dividing the sum of the frictional head loss and elevation head with average operating pressure head as:

$$P_{vl} = \frac{h_{fl} \pm h_{el}}{h_{al}}$$

P_{vl} = pressure variation of lateral line in fraction

h_f = frictional head loss of lateral line in m

h_a = average operating pressure head of lateral line in m

h_e = elevation head, which is (+) for lateral line running upward from the inlet and

(-) for downward case in m.

Lateral line

Lateral line carries water from submain and feeds to the individual drippers. The laterals are small diameter flexible pipes or tubes made up of low- density polyethylene (LDPE) or linear low-density polyethylene (LLDPE) of 12mm, 16mm, 18 mm, 20 mm and 22 mm diameter. They can withstand the maximum pressure of 2.5 to 4 kg/cm^2.

Frictional head loss

For lateral pipelines, the total friction head loss is equal to the sum of the losses between the outlets. However, the frictional head loss along the lateral and submain lines can also be calculated by multiplying with multiple outlet factor as:

For lateral line

$$h_{fl} = k \frac{{Q_l}^{1.75}}{{D_l}^{4.75}} L_l \times F$$

Where,

h_{fl} = frictional head loss of lateral line in m

Q_l = lateral discharge in L/s

D_m = lateral diameter in mm

L_l = length of lateral in m

K = constant (1.789x10^5)

F = multi-outlet factor which is explained to calculate the frictional head loss in the following sub section

Multiple outlet factors

A factor F for pipelines with equally spaced multiple outlets and outflow at the downstream end was derived by researchers. The proposed factor is a function of the number of outlets along the pipeline and also a function of the friction formula used. Factor F allows head loss in such pipelines to be computed directly provided the first outlet is one outlet spacing distance from the pipeline inlet. Factor F allows the design of segments of pipelines with multiple outlets. The first outlet factor is at a distance equal to emitter or outlet spacing from the inlet was given by Christiansen (1942) [9] as:

$$F = \frac{1}{m+1} + \frac{1}{2N} + \frac{\sqrt{m-1}}{6N^2}$$

Where,

F = Christiansen adjustment coefficient;

m = exponent of the flow rate

N = number of emitters.

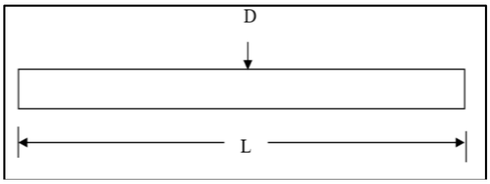

Fig 1: Layout of lateral line

Development of Design Charts for Lateral line

The design charts were developed for uphill slopes and different values of lengths, diameters, emitter spacing, emitter discharge, lateral discharge and average operating pressure heads. Different charts were developed for different cases of lateral lines. The graphical relationships were so established that the effect of diameter, lateral length, slope, frictional head loss and pressure variation can be easily analysed. For better readability two separate design charts were prepared – one for smaller subunit and other for bigger subunit.

The design charts for single pipe size lateral line of drip irrigation system to serve vegetable and orchard crops were developed. The design charts were prepared in combination of three portions. The lower portion of the design chart is based on the lateral length, emitter spacing, and emitter discharge. The middle portion of the design charts are relating lateral discharge the diameter and lateral length, whereas the upper portion was plotted to relate elevation head, average operating head and frictional loss are presented below.

Smaller Subunit Design Chart

This design charts were prepared for smaller sizes laterals irrigating subunit of drip irrigation field having vegetable crops requiring lesser amount of water. In the lower part of the chart, the length of lateral ranging from 40 m to 150 m on horizontal axis; emitter spacing from 0.5 m to 10 m and emitter discharge from 2 L/h to 6 L/h on inclined axis were plotted. The lateral discharge ranging from 0 to 0.111m on horizontal axis, diameter from 12 mm to 16 mm and lateral length from 40 m to 150 m on inclined axis were plotted at the middle portion of the design chart. The upper part is including the friction head loss ranging from 0 to 7 m on the horizontal axis, the value of pressure variation multiplied by average operating pressure ranging from 1 m to 6 m and slope from 0.5% to 5% on the inclined axis and lateral length on upper horizontal axis were plotted as shown in Figure for upward slopes respectively.

Larger Subunit Design Chart

This design chart was prepared for bigger sizes laterals irrigating subunit of drip irrigation field having orchard crops requiring larger amount of water. This design charts was prepared by considering the larger diameter ranging from 18 mm to 22 mm, emitter spacing from 0.5 m to 7 m on inclined axis giving the similar way as mentioned above for the smaller subunit.

Technique of Using Design Charts for Lateral Line

The letters representing LPDC, MPDC, and UPDC in the flow chart have been used for designating Lower Part of Design Chart, Middle Part of Design Chart and Upper Part of Design Chart respectively. Further, VA and HA stand for vertical and horizontal axis. The symbol ↓ and ← show the movement in vertical and horizontal directions. The flow diagram was so developed that it is self-explanatory to design lateral pipelines of drip irrigation system on zero, upward slopes for given field conditions.

The technique of using design charts for lateral line is shown in Figure. Before applying the technique of using the design chart for a particular case, the required data related to lateral length (L), emitter spacing (S_e), emitter discharge (q_e), diameter (D), slope (s) and average operating head (h_a).

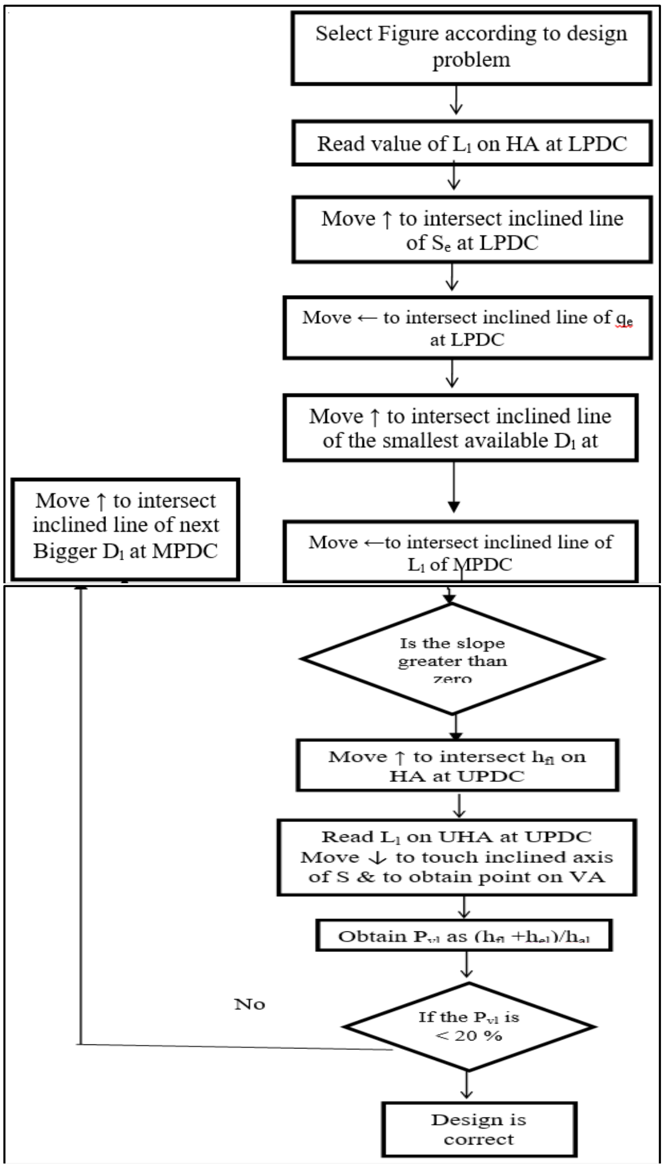

Fig 2: Flow diagram showing technique of using design charts for lateral line

Results and Discussion

Design Charts for Lateral Line

The drip irrigation lateral lines for different field slopes were designed with the help of developed charts. The design charts can be used by choosing a diameter, length of lateral, emitter spacing, average emitter discharge, different slopes and average operating pressure. The acceptability of the design for the given field conditions is based on the allowable pressure head variation limit.

The design charts prepared according to methodology mentioned in fig. 2 is shown in Figures 3. Each design chart mainly shows the combination of three portions having been plotted for different variables and better readability. The design chart for the lateral line of drip irrigation system on upward slope is schematically shown in Figure 3 and 4. The applicability of design charts is mentioned in the following section.

Upward slope

For designing the lateral line of smaller subunit of drip irrigation system on upward slope the lower portion of figure shows the lateral length ranging from 40 m to 150 m on the horizontal axis with emitter spacing ranging from 1.5 m to 10 m and average emitter discharge ranging 2 L/h to 6 L/h on the inclined axis. The middle portion of figure shows the lateral discharge ranging from 0 to 0.333 L/s on the horizontal axis with diameters ranging from 18 mm to 22 mm and lateral length ranging from 40 m to 150 m on the inclined axis. The upper portion shows the friction head loss ranging from 0 to 7 m on the horizontal axis with the value of pressure variation multiplied by average operating pressure ranging from 1 m to 6 m on the inclined axis.

Example problem: Design a lateral line to be laid on an upward slope using the following data.

Lateral length (L_l) = 130 m, Emitter spacing (S_e) = 1.5 m, Emitter discharge (q_e) = 4 L/h, Average operating pressure (h_a) = 15 m,
Slope (s) = 0.5%, Pressure variation (P_{vl}) = 20%.

Solution: This design problem was solved by using Figure 3 to consider smaller subunit. To perform the activities and obtain the stepwise values on the design chart as presented in Table 1. The flow diagram shown in Figure 2. Was used. It can be seen from Table 1. That the value of pressure variation is very close to 20 percent; therefore the diameter of lateral line as 14 mm is selected without any possibility of designing two pipes size lateral line. It is quite meaningful to mention that the value of 12 mm chosen as the smallest diameter at step 6 of Table 1. Was rejected because of higher pressure variation than 20 percent; and hence the next bigger diameter was chosen. The results obtained from the design charts were verified with hand calculations by using some equations. The values obtained from design charts and hand calculations were closely matching.

Table 1: Graphical solution of lateral line on upward slope

Portion of Design Charts	Step	Activities on Design Charts	Values on Design Chart
LPDC, Fig.3	1	Read value of L_l on the HA	130 m
	2	Move ↑ to intersect inclined line of S_e	1.5 m
	3	Move ← to intersect inclined line of q_e	4 L/h
MPDC, Fig.3	4	Move ↑ to intersect inclined line of D_l	14 mm
	5	Move ← to intersect inclined line of L_l	130 m
UPDC, Fig.3	6	Move ↑ to intersect the HA and obtain the value of h_{fl}	2.25 m
	7	Read L_l on upper HA move ↓ touch inclines line of s to obtain h_{el}	0.65 m
	8	Read the value of $0.2h_{al}$ on inclined axis	3 m
	9	Using the values of steps 6, 7, and 8; obtain the pressure variation as: $(h_{f\,l} + h_{el})/h_{al}$	0.19

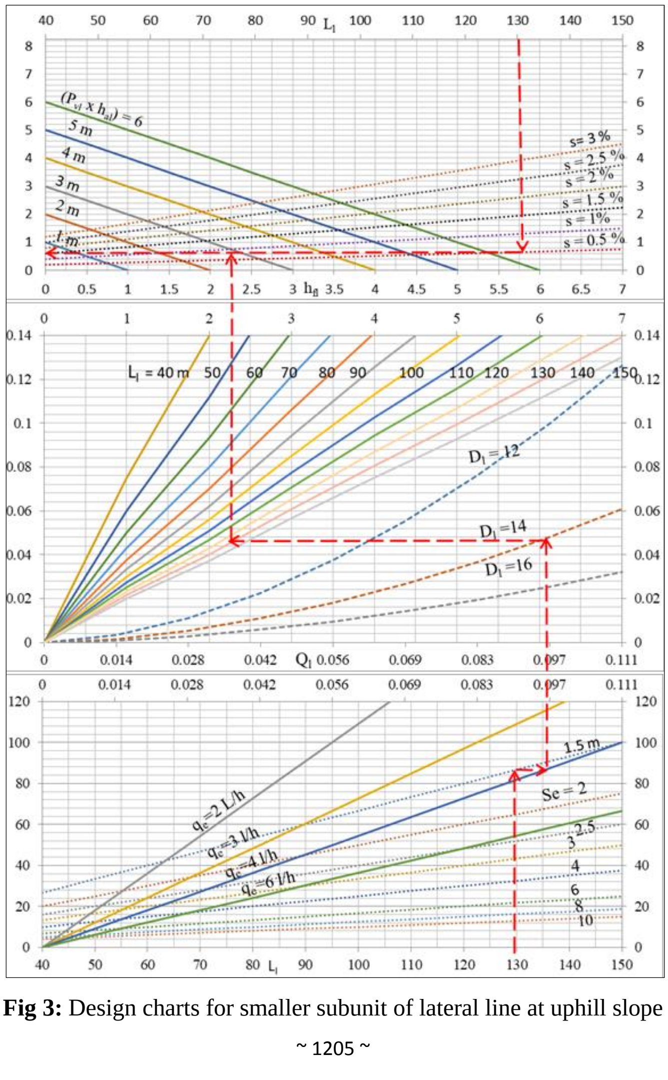

Fig 3: Design charts for smaller subunit of lateral line at uphill slope

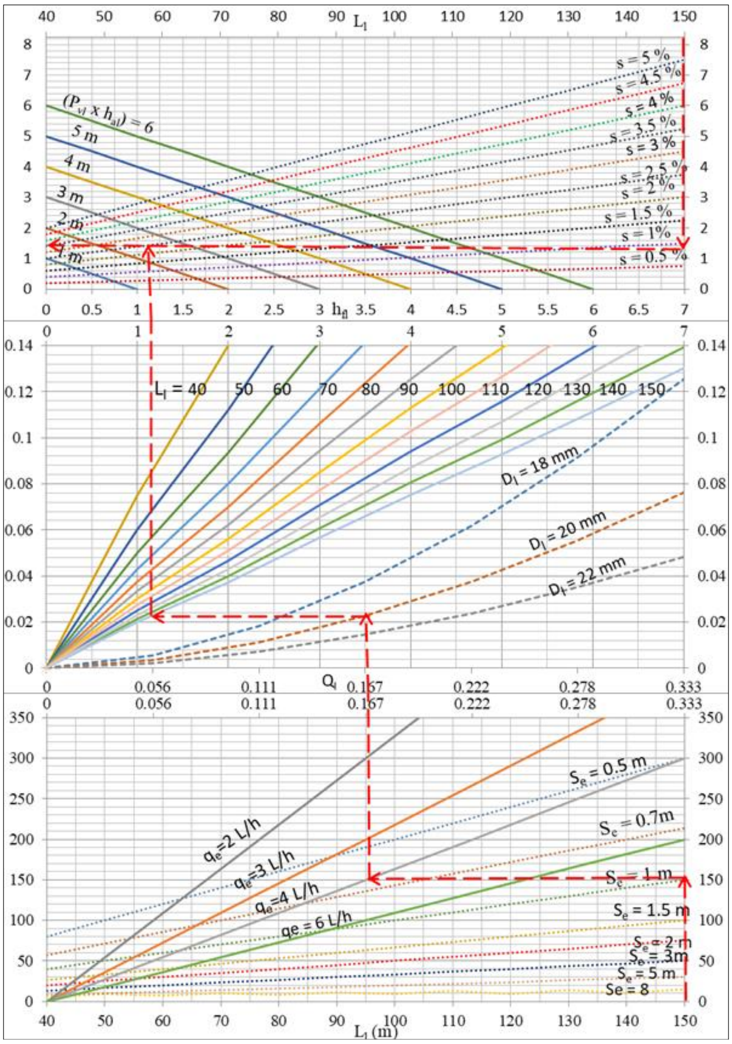

Fig 4: Design charts for bigger subunit of lateral line at uphill slopes

Conclusions

The design charts for lateral line was developed to read the given data as lateral length, emitter spacing, average emitter discharge, diameter, average operating head and slope on different axes; and to obtain the values of frictional head loss and pressure variation as output results. The technique of using design charts was derived from the development process of design charts and mentioned separately with the help of flow diagrams. The application of design charts was shown by solving design problems for lateral pipelines of drip irrigation at upward slopes. The solutions of design problems obtained by the developed design charts were presented in tabular forms and compared with the hand calculation to verify the results.

The developed design charts based on the allowable pressure head variation can be easily and accurately used to design lateral lines at upward slopes for any given values of field and manufacturers' data. The design charts are having flexibility to consider any value of pressure variation in the lateral lines rather than fixing a particular value such as 20 percent. This will help in obtaining different design alternatives to carry out the cost analysis. These designs charts are very simple and easy to understand even by non-technical persons for designing the lateral after practicing few numbers of times. Based on the development methodology the design charts can be easily prepared and extended according to choice of designer and field/manufacturers' requirements.

References

1. Allen RG. Relating the Hazen–Williams and Darcy–Weisbach friction loss equations for pressurized irrigation systems. Applied Engineering in Agriculture. 1996; 12(6):685-693.
2. Anwar AA. Factor G for pipeline with equally spaced multiple outlets and outflow Journal of Irrigation and Drainage Engg, ASCE. 1999; 122(1):34-38.
3. Bagarello V, Ferro V, Provenzano G, Pumo D. Evaluating pressure loss in a drip irrigation lines. Journal of Irrigation and Drainage Engg, ASCE. 1997; 123(1):1-7.
4. Barragan J, Wu IP. Simple Pressure Parameters for Micro-irrigation Design. Bio systems Engineering. 2004; 90(4):463-475.
5. Bralts V, Fand Wu IP. Emitter flow variation and uniformity for drip irrigation. ASAE Paper No. 79-2099, 1979.
6. Bralts VF. Field Performance and evaluation in Trickle Irrigation for Crop Production. Amsterdam, Elsevier, 1986.
7. Bralts VF, Gitlin HM. Manufacturing variation and drip irrigation uniformity. Tran ASAE. 1981; 24(1):113-119.
8. Bresler E. Analysis of trickle irrigation with application to design problems. Irrigation Science. 1978; 1:03-17.
9. Christiansen JE. Irrigation by sprinkler. Calif Agri. Exp. Sta.Bul. 1942; 670:94.
10. Jain BH. Microirrigation Technologies-Experiences and Issues Involved in their Promotion in Developing

Countries, Key note address, Internation system, CBIP-JISL, Maharashtra, India, 2000a.
11. Kameli D, Keller J. Trickle irrigation lateral design. Glendora, California: Rain Bird sprinkler manufacturing crop, 1975.
12. Kang Y, Nishiyama S. Analysis of microirrigation systems using a lateral discharge equation. TRANS ASAE. 1996a; 39-3:921-929.
13. Kang Y, Nishiyama S. Analysis and design of microirrigation laterals. J. Irrig. Drain. Eng. ASCE. 1996b; 122-2:75-82.
14. Kang Y, Nishiyama S. Design of microirrigation submain units. J. Irrig. Drain. Eng. ASCE. 1996c; 122(2):82-89.
15. Kang Y, Nishiyama S. Design of microirrigation submain units using the lateral discharge equations. Trans. Japanese Society Irrig. Drain. Reclamation Eng. 1996e; 182:241-252.
16. Keller J, Bliesner RD. Sprinkler andtrickle irrigation, Van Nostrand Reinhold, York, N.Y, 1990, 652.
17. Keller J, Kermeli D. Trickle irrigation design parameter. Trans. ASAE. 1974; 17(4):678-684.
18. Mahar PS, Singh RP. Computing Inlet Pressure Head of multi-outlet pipelines. J Irrig. Drain. Eng. ASCE. 2003b; 129(6):464-468.
19. Mane MS, Ayare BL, Magar SS. Principles of Drip Irrigation System, Pub. Jain Brothers, Jain Brothers, 16/873, East Park Road, New Delhi. 2003b; 30-31, 36-37, 41-49.
20. Nakayama FS, Bucks DA. Trickle irrigation for crop production. Amsterdam, Elsevier, 1986.
21. Sadeghi SH, Mousavi SF. A unified approach for computing pressure distribution in multi-outlet irrigation pipelines. Trans. Civil Eng. 2012; 36(2):209-223.
22. Solomon K, Keller J. Trickle Irrigation uniformity and efficiency. J. Irrig. Drain. Eng. ASCE. 1978; 104(3):293-306.
23. Wu IP, Gitlin HM. Drip irrigation design based on uniformity. Trans. ASAE. 1974; 17(3):157-168.
24. Wu IP, Gitlin HM. Design of drip irrigation lines with varying pipe sizes. Trans. ASAE. 1977; 24(2):330-339.
25. Wu IP, Barragan J. Design criteria for microirrigation systems. Trans. ASAE. 2000; 43(5):1145-1154.
26. Wu IP, Sarawatari CA, Gitlin HM. Design of drip irrigation lateral length on uniform slopes. Irrigation Science. 1983; 4:117-135.