

Pressure-Discharge and Hydraulic Gradient along the Lateral of the Drip Irrigation System for Okra

Abstract

Micro irrigation system should ensure relatively same amount of water to each plant along the total length of lateral line. In general, the drip irrigation systems are low to medium operating pressure head systems with a pressure requirement in range of 0.5 kg/cm² to 2.5 kg/cm² depending on the area irrigated and field layout geometry. However, since these systems are pressure irrigation systems which require appropriate operating pressure heads to deliver the required rates of flow, the inevitable frictional head losses are to be compensated for maintaining uniformity in water application. Hence, the hydraulic gradient compensation needs to be achieved by some viable mechanism so that the inequality in pressure heads and discharges can be eliminated or minimized. The crop production will have its maximum yield and water use efficiency only one the water distribution uniformities at its the highest. Hydraulic gradient compensation assumes a vital role in compensating the operating pressure heads as well as the emitter discharges. The hydraulic gradient compensated drip lateral layout registered high order of water distribution uniformity in the range of 97.8% and irrigation usage efficiency in the range of 17.98 kg/ha/mm to 20.69 kg/ha/mm for 2 lph emitter arrangements.

Keywords: Pressure, Discharge, Hydraulic gradient, Lateral

Introduction

Water remains as the indispensable natural resource anchoring and fortifying all forms of life in the world. Agriculture maintains its cult status as the primary consumer of water in India. According to UNO, water crisis is the major threat for mankind in 21st century (as quoted by Meghanatha Reddy *et al.*, 2007).The indispensability of micro irrigation system was well recognized among the farming community during the last five years in Tamil Nadu. Effective utilization of every drop of water through adoption of appropriate technology is imperative for improving crop productivity to sustain agricultural production and to achieve desirable improvements in the living standards of all categories of farmer.

28 The response of okra to drip irrigation in terms of yield improvement was found to be
29 different in different agro climatic and soil conditions in India. The increase in the yield of okra
30 to the tune of 40% was reported under drip irrigation (Patil, 1982; Sivanappan et al., 1987).

31 Aniejhon et al. (2000) studied the effect drip and sprinkler irrigation on bhendi,-??? and
32 found that the plant height, yield and water use efficiency were higher in drip irrigation when
33 compared to sprinkler irrigation.

34 . A coefficient of manufacturing variation integrates the discharge fluctuations along a
35 lateral for a given operating pressure. Its values are found to be greater for pressure
36 compensating emitters than for non-compensating emitters (Özekici and Sneed, 1995).Based on
37 the coefficient of variation of pressure head along a lateral line and the variation of emitter flow
38 caused by manufacturers, Anyoji and Wu et al. (1987) developed a technique using a statistical
39 approach. Using Taylor's theories, mean emitter flow could be derived by considering the
40 pressure head and proportionality constant k in the emitter equation $q=kx$, as two random
41 variables. The coefficient of variation of pressure head was statistically determined from the
42 average and variance of pressure head which was affected by friction and slope changes along
43 the lateral line.

44 The impact of friction losses are technically depicted by the hydraulic gradient along the
45 multi outlet pipe flow directions. In general the drip irrigation systems are low to medium
46 operating pressure head systems with a pressure requirement in range of 0.5 kg/cm² (5 m of
47 water head) to 2.5 kg/cm² (25 m of water head) depending on the area irrigated and field layout
48 geometry. From the area increase naturally the length of laterals and sub mains will also
49 increase. The head loss due to friction also increase prepausally resulting in a high degree of
50 variation in the operating pressure heads and the corresponding emitter discharges from head to
51 tail end of the field.

52 Emitter is a main device of drip irrigation system. It is used to dissipate pressure and to
53 discharge a small uniform flow or trickle of water at a constant rate at several points along a
54 lateral. It is designed in such a way that the flow rate does not vary significantly with minor
55 changes in pressure across the lateral. The properties of emitters that play a vital role in
56 designing a drip irrigation system are discharge variation due to manufacturing tolerance,
57 closeness of discharge-pressure relationship to design specifications, emitter discharge exponent,
58 operating pressure range, pressure loss in laterals due to insertions of emitters and stability of the

59 discharge-pressure relationship over a long period of time. Hence, a study was formulated to find
60 the impact of compensating hydraulic gradient along laterals on water distribution uniformity
61 under drip irrigation.

62 **Material and Methods:**

63 **Methodology**

64 Experiment was conducted in PFDC farm (Eastern Block-NA4) of Tamil Nadu
65 Agricultural University, Coimbatore, Tamil Nadu. The farm is located at 11°N latitude and 77°E
66 longitude with at an altitude of 427 m above MSL.

67 **Hydraulic gradient compensation (Turbulent flow through smooth pipes)**

68 In a multiple outlet pipe line flow distribution system like the drip irrigation layout, the
69 hydraulics of flow through smooth pipe can be applied considering the turbulent flow of water.
70 Due to such condition, from the head end to tail end of the multiple outlet lateral line head loss
71 due to friction along the flow causes the gradual reduction the operating pressure heads from
72 emitter to emitter, thereby causing proportional variation in the corresponding discharge too,
73 along the laterals (or along the sub mains reduction in operating pressure heads and the
74 corresponding variation in the lateral discharge) are inevitable due to the decreasing trend
75 exhibited by the hydraulic gradient as

$$76 \quad H_x = H - H_f \left(1 - \left(1 - \frac{x}{L} \right)^{m+1} \right)$$

77 Where

78 H_x = Operating pressure head at any distance x from the junction point, of lateral

79 H_f = The total head loss due to friction along the multi outlet pipe in meter of water

80 L = Total length of the lateral submain as the case may be, in meter

81 x = The distance at which the operating pressure head needs to be predicted

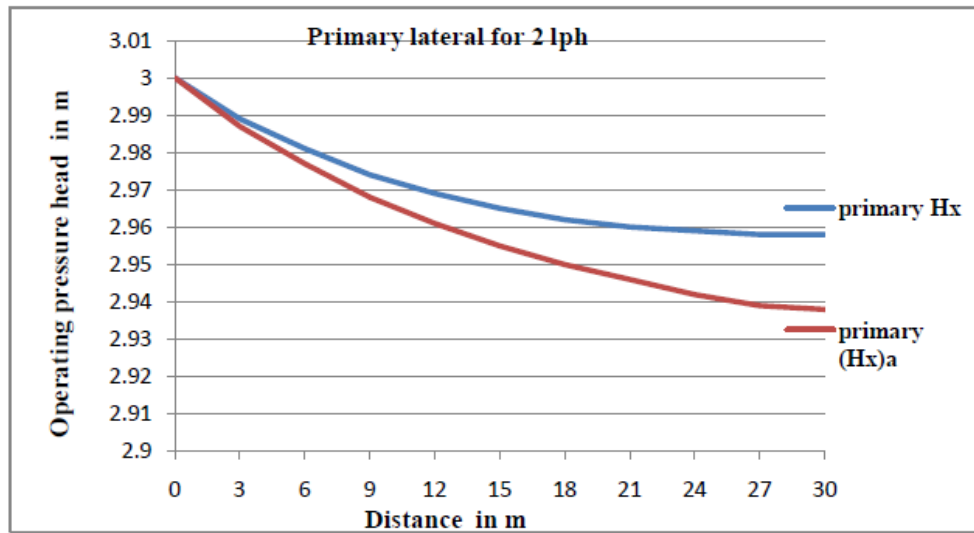
82 m = Exponent of discharge depend on the formula used

83 $m = 2$ Darcy-weisbach theoretical formula and manning formula

84 $m = 1.75$ for Darcy-weisbach empirical formula

85 The dip in the hydraulic gradient at any distance can be replenished by superposing an
86 equal and opposite hydraulic gradient, which is known as hydraulic gradient compensation.

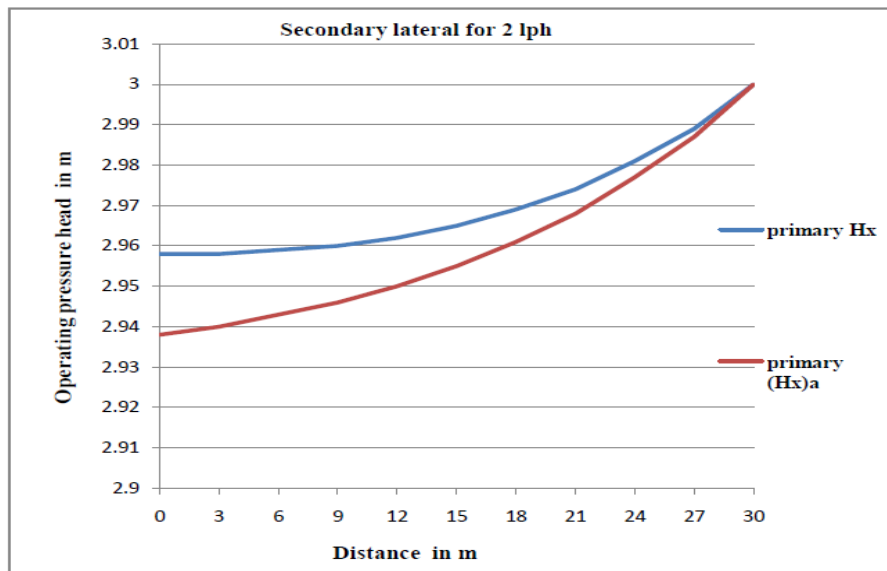
87 Fig. 1 shows the actual and theoretical pressure head variation for different distance. To achieve
 88 this another lateral needs to be incorporated for the same line of plants on the other side in the
 89 opposite direction. That is mirror image of the same hydraulic gradient needs to be generated but
 90 in the opposite direction(Fig 2). However, this mirror imaged hydraulic gradient should act in
 91 such a way that the head loss due to friction up to distance x the origin hydraulic gradient should
 92 be compensated as the complementary operating pressure head by the super imposed hydraulic
 93 gradient in the direction (Fig 3).



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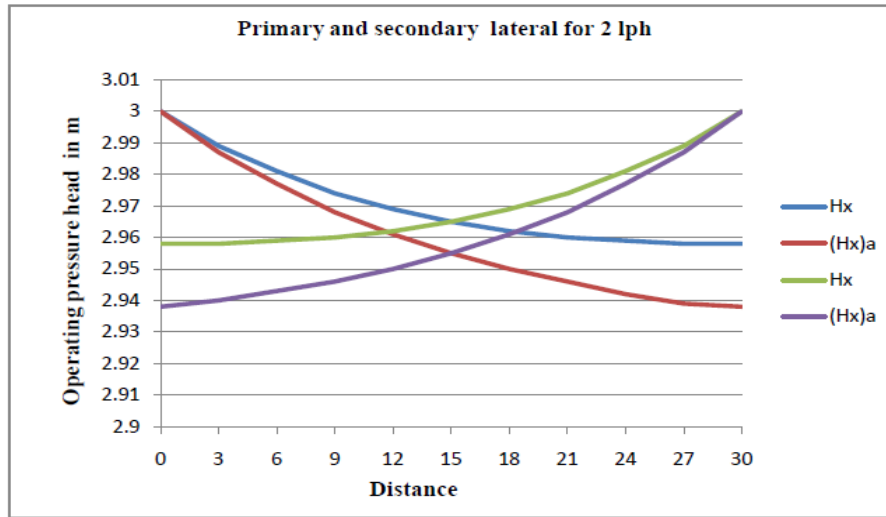
Fig 1 Hydraulic gradient profile for 2 lph primary lateral



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Fig 2 Hydraulic gradient profile for 2 lphSecondary lateral



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Fig 3 Hydraulic gradient profile for 2 lph Primary and Secondary lateral

100 **Result and Discussion**

101 Table 1 and 2 shows the observations on the 2 lph designated emitter discharges for different
 102 operating pressure heads in a drip system obtained as follows

103 **Table 1 Discharge Vs operating pressure head at emission points(primary lateral/ 2 lph)**

Primary Emission point in X	0	3	6	9	12	15	18	21	24	27	30
H in m	3	2.989	2.981	2.974	2.969	2.965	2.962	2.960	2.959	2.958	2.957
q in lph (q ₁)	2	1.999	1.997	1.993	1.990	1.988	1.986	1.985	1.984	1.983	1.982

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105 **Table 2 Discharge Vs operating pressure head at emission points(Secondary lateral/ 2 lph)**

Secondary emission point in X	30	27	24	21	18	15	12	9	6	3	0
H in m	2.957	2.958	2.959	2.960	2.962	2.965	2.969	2.974	2.981	2.989	3
q in lph (q ₂)	1.982	1.983	1.984	1.985	1.986	1.988	1.990	1.993	1.997	1.999	2
q ₁ +q ₂	3.982	3.982	3.981	3.978	2.990	3.976	2.990	3.978	3.981	3.982	3.982

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107 Since the experimental plot is a confined area limited to length of lateral 30 m only the
 108 variations the operating pressure head as well as the corresponding emitter discharges are not so
 109 appreciable. Hence the uniformity coefficient was worked out for this limited length of lateral
 110 both the lateral without hydraulic gradient compensation and that with hydraulic gradient

111 compensation expiated approximate same uniform coefficient that is 0.99 which is unusual for a
112 lateral length in real field layout with lengths more than 50 m up to or above 100 m .

113 **Irrigation water usage efficiency**

114 The irrigation water usage efficiency in the present context refers to the yield of
115 vegetable realized in kg/ha of land per mm of irrigation given. Table 3 furnishes the
116 comprehensive results of yield and irrigation water usage efficiency for the treatment conditions.

117 **Table 3 Irrigation Usage Efficiency (IUE)**

S.No	Particular	Yield in kg/ha	IUE in kg/ha/mm of water
1	2 lph without hydraulic gradient compensation (control 2)	7407.40	17.98
2	2 lph with hydraulic gradient compensation	8518.51	20.69

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119 **IUE for 2lph lateral without hydraulic gradient compensation**

120 From the table the yield of bhendi realized 7407.40 kg/ha against a depth of irrigation
121 412.02 mm of water. The irrigation water usage efficiency is projected 17.98 kg/ha/mm of
122 irrigation. In this plot of no hydraulic gradient compensation the head reaches here soon good
123 crop stand and yield while tail reaches where slightly lagging begin, possibly due to the gradual
124 reduction of operating pressure head from head to tail end with propositae decreases in the
125 emitter discharges.

126 **IUE for 2lph lateral with hydraulic gradient compensation**

127 From the table the yield of bhendi realized 8518.51 kg/ha against a depth of irrigation
128 411.736 mm of water. The irrigation water usage efficiency is projected 20.69 kg/ha/mm of
129 irrigation. In this plot of hydraulic gradient compensation, the crop stand was good and uniform
130 right to head to tail end possibly due to compensated discharges variation along the lateral
131 line. Data could be agreed with Mansour (2015), Mansour and Aljughaiman (2015), Mansour and
132 El-Melhem (2015), Mansour et al., (2015 a; b), and Mansour et al., (2016 a, b; c).

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134 **Conclusion**

135 The present study analyzed the hydraulic gradient pattern under non-compensated as well
136 as compensated conditions along the drip laterals. For a drip lateral length of 30 m with a
137 distribution of 2 lph emitters the friction head losses were found to be minimum and hydraulic
138 gradient compensation would help only to smaller extent of pressure and discharge
139 compensations. Though hydraulic gradient compensation supplements to the deficit in irrigation
140 water delivered according to changes in the operating pressure head, it warrants the provision of
141 one more drip lateral in the opposite direction of the primary line thereby increasing both the
142 emitter discharges and the cost of additional drip laterals.

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