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/cm^2 to 2.5 kg/cm^2 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 achieve 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.

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

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

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

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The impact of friction losses are technically depicted by the hydraulic gradient along the multi outlet pipe flow directions. 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 (5 m of water head) to 2.5 kg/cm2 (25 m of water head) depending on the area irrigated and field layout geometry. From the area increase naturally the length of laterals and sub mains will also increase. The head loss due to friction also increase propoorsionally anally resulting in a high degree of variation in the operating pressure heads and the corresponding emitter discharges from head to tail end of the field.

Emitter is a main device of drip irrigation system. It is used to dissipate pressure and to discharge a small uniform flow or trickle of water at a constant rate at several points along a lateral. It is designed in such a way that the flow rate does not vary significantly with minor changes in pressure across the lateral. The properties of emitters that play a vital role in designing a drip irrigation system are: discharge variation due to manufacturing tolerance, closeness of discharge-pressure relationship to design specifications, emitter discharge exponent, operating pressure range, pressure loss in laterals due to insertions of emitters and stability of the discharge-pressure relationship over a long period of time. Hence, a study was formulated to find the impact of compensating hydraulic gradient along laterals on water distribution uniformity under drip irrigation.

Methodology

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

Hydraulic gradient compensation (Turbulent flow through smooth pipes)

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

$$Hx=H-Hf(1-(1-x/L)m+1)$$

Where

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

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

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

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

m = Exponent of discharge depend on the formula used

m = 2 Darcy-weisbach theoretical formula and manning formula

m = 1.75 for Darcy-weisbach empirical formula

The dip in the hydraulic gradient at any distance can be replenished by superposing an equal and opposite hydraulic gradient, which is known as hydraulic gradient compensation.
Fig. 1 shows the actual and theoretical pressure head variation for different distance. To achieve this another lateral needs to be incorporated for the same line of plants on the other side in the opposite direction. That is mirror image of the same hydraulic gradient needs to be generated but

in the opposite direction (Fig 2). However this mirror imaged hydraulic gradient should act in such a way that the head loss due to friction up to distance x the origin hydraulic gradient should be compensated as the complementary operating pressure head by the super imposed hydraulic gradient in the direction (Fig 3).

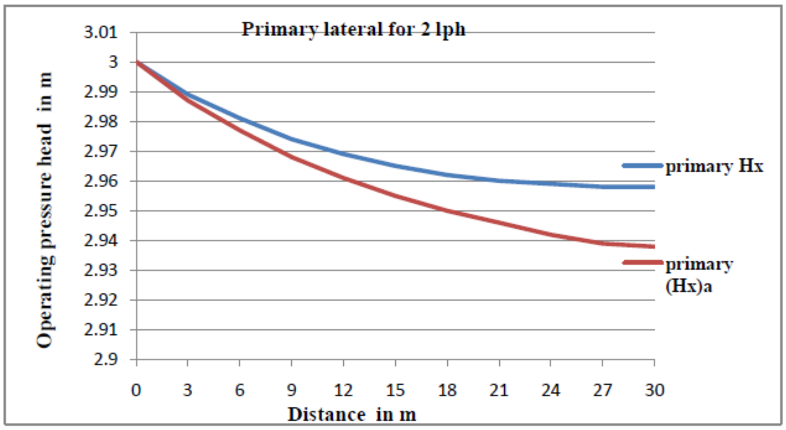

Fig 1 Hydraulic gradient profile for 2 lph primary lateral

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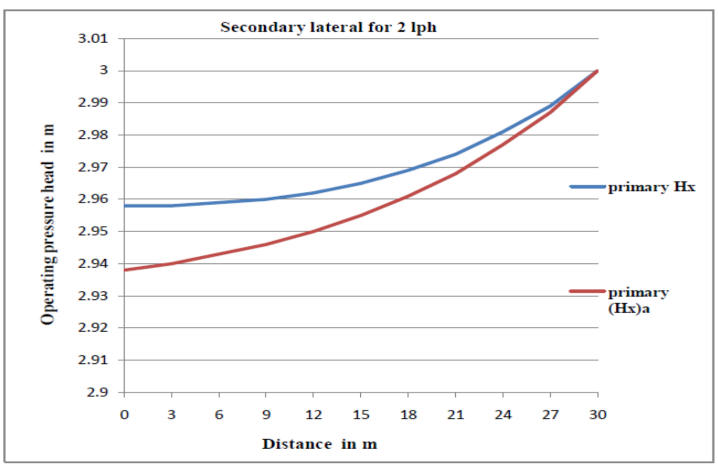

Fig 2 Hydraulic gradient profile for 2 lph Secondary lateral

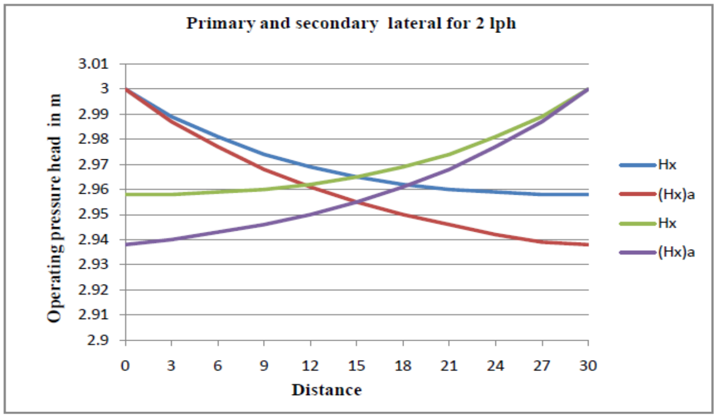

Fig 3 Hydraulic gradient profile for 2 lph Primary and Secondary lateral

Results and Discussion

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

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

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

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

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Irrigation water usage efficiency

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

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

IUE for 2lph lateral without hydraulic gradient compensation

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

IUE for 2lph lateral with hydraulic gradient compensation

From the table the yield of bhendi realized 8518.51 kg/ha against a depth of irrigation 411.736 mm of water. The irrigation water usage efficiency is projected 20.69 kg/ha/mm of irrigation. In this plot of hydraulic gradient compensation the crop stand was good and uniform right to head to tail end possibly due to compensated discharges variation along the lateral line.

Conclusion

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

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