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RESEARCH ARTICLE

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Hydraulic performance of drip irrigation system

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Abstract

The experiment was conducted at the leveled field to evaluate the hydraulic performance of drip irrigation system with two emission devices *viz.,* online dripper (8 lph) and drip-in dripper (1.3 lph) for varying pressure *viz.,* 0.75, 1 and 1.25 kg/cm^2. Experimental set up was installed for determination of uniformity coefficient, emission uniformity and coefficient of variation. The result revealed that different hydraulic measures such as uniformity coefficient, emission uniformity and coefficient of variation at different operating pressure for online drip irrigation at 0.75 kg/cm^2 was 97.05%, 95.75% and 2.94%, respectively, similarly for the operating pressure 1.00 kg/cm^2 it was 97.99%, 97.08% and 2.00% and for 1.25 kg/cm^2 it was 98.15%, 98.33% and 1.84% also for inline drip irrigation uniformity coefficient, emission uniformity and coefficient of variation for operating pressure 0.75 kg/cm^2 was 97.25%, 98.72% and 2.74% and for pressure 1.00 kg/cm^2 it was 97.30%, 99.44% and 2.69%, respectively, and at 1.25 kg/cm^2 it was 98.92%, 99.53% and 1.07 %, respectively. The above result shows that the uniformity coefficient and emission uniformity increased while coefficient of variation decreased as operating pressure increased for all emission devices.

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Key words: Hydraulic Performance, Drip irrigation, Uniformity coefficient, Emission uniformity, Coefficient of variation

INTRODUCTION

An important factor in drip irrigation design procedure, is determination of energy loss in drip lateral, emitter spacing, pipe diameter, lateral length, ground slope and emitter flow rate, however, since a lateral line has a large number of emitter, this minor loss multiplies into significant loss, pressure losses in the lateral line, which ultimately causes the emitter flow variation along the lateral depends on the length of lateral line and number of emitters and type of drip irrigation system that is online or inline drip irrigation system. Keeping this in view, study was conducted in two irrigation system such as inline and online irrigation system for variation in discharge rate and pressure head along the lateral.

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MATERIALS AND METHODS

The experiment was conducted to study the hydraulic performance of drip irrigation system at central farm of Aditya College of Agrilcutural Engingring and Technology Beed. The trial was conducted during the month of November 2010.

Experimental setup:

An isolated drip irrigation system was used under field test. Electrical operated submersible pump of 5 hp was used to pump water from open well to drip irrigation system. A screen filter and sand filter was installed between mainline and delivery pipe of the pumping set. HDPE pipes of 75mm diameter were used for mainline and PVC plastic pipes of 63mm were used for submain. Low density polyethylene (LDPE) plastic pipe of 16mm diameter were used for lateral lines. The flow rate or discharge of emitter was collected in catch cans and then measured with measuring cylinder.

Experimental setup for on-line drip irrigation system:

Drip irrigation a system having a lateral size of 16mmof on line drip irrigation systems were used for the study of hydraulic performance of drip irrigation systems. Randomly three laterals were selected from the submain line and also four emission devices having discharge of 8 lph were selected over each lateral for the study. The pressure was adjusted by using the bypass valve. The discharge of emitter at various pressures as 0.75kg/cm^2, 1.00kg/cm^2 and 1.25kg/cm^2 was measured with the measuring cylinder.

Experimental setup for in-line drip irrigation system:

Same set up was used for the in line drip irrigation systems instead of online drip irrigation systems having lateral size of 16mm of in line drip irrigation having discharge of 8 lph was used for the study . Randomly three laterals were selected from the submain line and also four emission devices were selected over each lateral for the hydraulic performance of drip irrigation systems. The pressure was adjusted by using the bypass valve. The discharge of emitter at various pressures as 0.75kg/cm^2, 1.00kg/cm^2 and 1.25kg/cm^2 was measured with the measuring cylinder.

Uniformity coefficient :

For determination of uniformity coefficient of emitter *i.e.* in-line and on-line drip irrigation system, the catch cans were placed at each selected emission devices of selected laterals. The system was operated at pressure 0.75 kg/cm^2, 1.00 kg/cm^2 and 1.25 kg/cm^2. The water was allowed to emitter in the catch cans for 1hr continuously. The volume of water collected in the catch cans was measured with the help of measuring cylinder. The precipitation depth was calculated by dividing the volume of collected water with cross sectional area of catch cans. These depth were used for computing the uniformity coefficient of the emitter calculated by the equation given by Christiansen (Michael, 1978)

$$UC = 100X\left[1 - \frac{\Sigma X}{mn}\right]$$

where,
UC = Uniformity coefficient (%)
m = Average of all observations.
n = Total number of observations.
X = Numerical deviation of individual Observation from average depth.

Emission uniformity (EU):

Emission uniformity is the measure of the uniformity of emitter discharge from all the emitter of drip irrigation system and is the single most important parameter for evaluating system performance. EU shows relationship between minimum and average emitter discharge. Emission uniformity of the emitter was calculated by the equation given below:

$$EU = \frac{\text{Minimum rate of discharge}}{\text{Average rate of discharge}} \times 100$$

Coefficient of variation (CV):

Coefficient of variation defines as the ratio of the standard deviation of flow to the mean flow for a sample number of emitters.

This parameter which can be used as a measure of emitter flow variation.Coefficient of variation of the emitter was calculated by the equation given below:

$$CV = \frac{Sq}{Qavg} x100$$

where,
CV = Coefficient of variation (%)
Sq = Standard deviation of the discharge rate for the sample
Q_{avg} = Average discharge rate

where,

$$\text{Standarddeviation}(Sq) = \sqrt{\left(\Sigma \frac{x2}{n} - \overline{x2}\right)}$$

where,
Σx = Square of the numerical deviation of the individual observation

$\Sigma \bar{x}$ = Mean of the observation
n = Total number of observation

Hydraulic characteristics:

Over the range of discharge the flow characteristics of emitters can be characterized by,

$$Q = kd\ H^x$$

where,
Q = emitter discharge, lph
K_d = constant of proportionality that characterizes

each emitter

H = Working pressure head at the emitter, m

X= emitter discharge exponent that is characterized by the flow regime.

To determine k_d and x the discharges at two different operating pressure heads must be known. The exponent x may be determined by measuring the slope of log-log plot of pressure head (H) vs discharges (q) or analytically by,

$$x = \frac{\log [---]^{q_1}_{q_2}}{\log [---]^{H_1}_{H_2}}$$

where,

X= emitter discharge exponent

q_1 = Emitter discharge at H_1 in lph.

q_2 = Emitter discharge at H_2 in lph

H_1 and H_2 = pressure head in m.

For different flow regime expected values of x are in given Table 1

Table 1 : ASAE (1985) emission device classification

Flow regime	X – value	Emitter type
Variable flow path	0.1	Pressure compensating
	0.2	
	0.3	
Vortex flow	0.4	Vortex
Fully turbulent flow	0.5	Orifice, Tortuous
Mostly turbulent flow	0.6	Longer spiral path
	0.7	
	0.8	
Mostly laminar flow	0.9	Micro tube
Fully laminar flow	1.0	Capillary

RESULTS AND ANALYSIS

For evaluation of drip irrigation system, an isolated drip irrigation system was operated under different operating pressures to study their hydraulic performance of drip irrigation system.

Uniformity coefficient:

The uniformity coefficient 98.15% for on line drip irrigation was maximum at 1.25 kg/cm² operating pressure and minimum 97.05% at 0.75 kg/cm² operating pressure. While for drip-in, the uniformity coefficient 98.92% was maximum at 1.25 kg/cm² operating pressure and minimum 97.25% at 0.75 kg/cm² operating pressure. Thus for a particular spacing uniformity coefficient increases as the operating pressure increases for all emission devices.

The increase in uniformity coefficient is mainly due to increase in average rate of discharge because, average deviation of rate of discharge is very low as compared to average rate of discharge, and hence it can be neglected as compared to average rate of discharge.

At a particular spacing, the average rate of discharge increased as the operating pressure head increased due to constant emission point per unit length of lateral. Hence uniformity coefficient increased as the operating pressure head increased for all emission devices.

The values of uniformity coefficient of different emission devices are given in Table 3 .

Table 2: Eemitter discharge at various operating pressure

Size of lateral	Discharge of on line emitter (lph) at different operating Pressure			Discharge of In line emitter (lph) at different operating Pressure		
	0.75 kg/cm²	0.75 kg/cm²	1.00 kg/cm²	0.75 kg/cm²	0.75 kg/cm²	1.00 kg/cm²
16mm	6.960	7.680	7.920	1.175	1.265	1.292
	7.200	7.440	7.850	1.165	1.270	1.300
	6.840	7.500	7.760	1.180	1.268	1.298
	6.720	7.464	7.890	1.160	1.265	1.305
16mm	6.600	7.500	7.930	1.165	1.272	1.303
	6.480	7.300	7.980	1.170	1.280	1.298
	6.840	7.620	7.820	1.185	1.285	1.292
	6.600	7.200	7.750	1.190	1.290	1.295
16mm	6.480	7.260	7.700	1.175	1.275	1.300
	6.900	7.200	7.790	1.180	1.270	1.305
	6.720	7.308	7.880	1.185	1.268	1.297
	6.840	7.500	7.700	1.175	1.265	1.295
Mean	6.765	7.416	7.830	1.175	1.272	1.298

Table 3: Hydraulic performance evaluation measure for different emission devices and operating pressure.

Emission Devices	Operating pressure Kg/cm^2	Hydraulic performance evaluation measure		
		UC (%)	EU (%)	CV (%)
Dripper	0.75	97.05	95.75	2.94
Dripper	1.00	97.99	97.08	2.00
Dripper	1.25	98.15	98.33	1.84
Drip-in	0.75	97.25	98.72	2.74
Drip-in	1.00	97.30	99.44	2.69
Drip-in	1.25	98.92	99.53	1.07

Emission uniformity:

Emission uniformity of the system decides the uniformity distribution of discharge by each emitter or uniformity distribution of water to each crop.

The emission uniformity 98.33% for on line drip irrigation was maximum at 1.25 kg/cm² operating pressure and minimum 95.75% at 0.75 kg/cm² operating pressure. While for drip-in, the emission uniformity 99.53% was maximum at 1.25 kg/cm² operating pressure and minimum 98.72% at 0.75 kg/cm² operating pressure. Thus, for a particular spacing, emission uniformity increases as the operating pressure increases for all emission devices.

The increase in emission uniformity is mainly due to increase in the ratio of minimum rate of discharge to the average rate of discharge.

At a particular spacing, the ratio of minimum rate of discharge to average rate of discharge increased as the operating pressure head increased due to constant emission point per unit length of lateral, and thus the emission uniformity increased as the operating pressure head increased for all emission devices. The values of emission uniformity of different emission devices are given in Table 3 .

Coefficient of variation:

The coefficient of variation 2.94% for on line dripper was maximum at 0.75 kg/cm² operating pressure and minimum 1.84% at 1.25 kg/cm² operating pressure. While for drip-in, the coefficient of variation 2.74% was maximum at 0.75 kg/cm² operating pressure and minimum 1.07% at 1.25 kg/cm² operating pressure. Thus for a particular spacing, coefficient of variation decreases as the operating pressure increased for all emission devices.

The increase in coefficient of variation is mainly due to increase in the average rate of discharge because a standard deviation of the rate of discharge is very-very small as compared to average rate of discharge. Hence, it can be neglected as compared to average rate of discharge. At a particular spacing, the average rate of discharge increased as the operating pressure head increased due to constant emission point per unit length of lateral. And thus, coefficient of variation decreased as the operating pressure head increased for all emission devices. The value of coefficient of variation of different emission devices are given in Table 3 .

Coefficient of manufacturing variation:

To decide the system good, average, marginal and excellent, it was necessary to determine the manufactures coefficient of emitters either point source or line source.

The coefficient of manufacturing variation decreases with increase in operating pressure for drip-in as well as dripper. The variation is largest for dripper at 0.75 kg/cm² at operating pressure and smallest for drip-in at 1.25 kg/cm² at operating pressure.

The same result of uniformity coefficient, emission uniformity and coefficient of variation was found as in evaluation of hydraulic performance of drip irrigation system by Kumar and Singh (2007).

The emitter discharge exponent of emitter under the study for different pressure ranges are presented in Table 4.

Table 4 : Emitter discharge exponent of online and in line drippers for different pressure ranges

Pressure ranges (kg/cm^2)	x- values for on lined rippers	x- values for on line drippers
0.75-1.00	0.3	0.2
1.00-1.25	0.2	0.1

Ideally emitter discharge exponent values x should be constant for an emitter however, for same emitter charges are very similar to k_d values emitter having minimum a value may be suitable for using pressure range. Here, it can be seen that for most of emitter x-value lies from 0.1 – 0.3 from variable flow path according to ASAE – emission device classification some value of x is less than 0.3 then the flow is variable an pressure compensating.

Conclusion:

– In the experiment it was observed that at a particular spacing, the uniformity coefficient and emission uniformity increased at operating pressure increase and coefficient of variation decreased, also operating pressure increased for all emission devices.

– The drippers were found most suitable for wide spacing which was 5m x 5m for anola crop.

– The drip-in was most suitable for close spacing which was 2m x 0.4m for sugarcane crop.
– The coefficient of manufacturing variation was lowest 1.07% and highest 2.74% for drip-in and dripper highest for 2.94% and lowest for 1.84%for dripper

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