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Performance evaluation of gravity fed inline drip irrigation system

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■ **ABSTRACT :** The field experiment was under taken on research farm of College of Agriculture Engineering and Technology, Dapoli, dist.- Ratnagiri (M.S.) to evaluation the performance of gravity fed inline drip irrigation system for cashew plantation. The system used inline drippers having the average discharge of 0.6 lit/hr. The design was done for 1 ha. area. The sizes (diameter) of the main line, sub main, lateral was computed as 40 mm, 12 mm and 6 mm, respectively, which was found to be less as compared to the conventional drip irrigation system. The emission uniformity of gravity fed inline drip irrigation system was found to be 85 per cent and was good for tested emitters as per ASAE interpretation. The vertical and radial movement of moisture was observed upto 60, 46 cm for 6 hrs and 80, 50 cm for 12 hrs, respectively which showed that the movement of moisture contour was faster in 6 hrs. as compared to 12 hrs. The moisture distribution pattern in gravel sandy loam lateritic soils showed that, the vertical movement of water was predominant than the lateral movement. The gravity fed inline drip irrigation system was found to be beneficial to small and marginal farmers of Konkan region of Maharashtra to provide the irrigation in remote areas.

■ **KEY WORDS :** Gravity fed drip irrigation, Design, Moisture distribution, Cost

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India having the geographical area is around 328 M ha. Out of that, 142.9 M ha is the net sow area and the area under the irrigation is only 88 M ha. The agriculture is the largest consumer of water. In India 91.6 per cent of water is used for irrigation purpose as compared to 84 per cent in Asia and 71 per cent in the world. At one time or the other, almost all the countries have benefited from "Green Revolution". The engine of this development has been irrigated water. Increasing competition with the urban, industrial and environmental sectors limits the quantities of water available for further irrigation expansion. For fulfilling this requirement there is necessary to change in physical system as well as in the management system. Gravity inline drip irrigation system use synonymous to drip irrigation system in case of water application but gravity inline drip system having advantage of energy saving.

Brandt *et al.* (1971) found that the application of water at higher rate increases the width of wetting pattern related to depth. Jobling (1972) suggested that the design criteria for the drip irrigation system should be based on the uniformity co-efficient of 98 per cent with a minimum acceptable co-efficient of 95 per cent. Keller and Karmeli (1974) have suggested two parameters to determine the uniformity of application of a trickle system. The emission uniformity (EU) suggested by them involves the relationship between minimum and average emitter discharge rates within the system. They noted that this relationship is the most important factor in distribution efficiency. They also recommended that an emission uniformity of 94 per cent or more is desirable and in no case the design should be 90 per cent.

Gutal *et al.* (1989) compared drip irrigation with furrow irrigation for vegetables with pressure compensating emitters. The uniformity and distribution uniformity for drip irrigation was 93.0 and 86.70 per cent for pressure compensating emitters. Firake and Salunkhe (1993) observed that soil moisture at any depth and time decreases with increase in operating pressure head and also seen that more the head, more was the time to saturate the root zone. Ravikumar *et al.* (2001) presented a method for the design of drip irrigation system for non-uniform outflow along the pipe using the energy gradient line approach.

Rajvir Sing *et al.* (1989) conducted an experiment on wetting front advance for varying rates of discharge from a trickle source. The result shows that the trickle discharges and types of soil have a significant effect on moisture front advance and volume of wetted soil profile and also concluded that rate of advance of wetting front in vertical as well as horizontal direction decreases with increase of elapsed time.

METHODOLOGY

The proposed study was undertaken to evaluate the gravity inline drip irrigation system for hilly areas at the research farm of College of Agril. Engineering and Technology, Dapoli, dist Ratnagiri (M.S.). The study area is situated at $17^0 45'$N latitude and $73^0 26'$E longitude an altitude of 250 m above mean sea level. The mean annual precipitation of region is 3423mm with minimum, and maximum temperature of 9.5^0C and 36^0C, respectively. Relative humidity varies between 55 to 85 per cent. The mean annual evaporation of the region is 4.5 mm/day ranging from 1.8 mm/day to 7.4 mm/day during experimental period. The topography of the region is undulating with the hilly terrain. The infiltration rate of the soil is about 6cm/hr and the textural classification of the soil is sandy loam with depth ranging from 40-60 cm.

In order to calculate manufacturers co-efficient of variation and emission uniformity the discharges from sixteen locations was measured and computed using standard procedure suggested by Christiansen (1942) and above mentioned equation.

The observed values of manufacturers co-efficient of variation and emission uniformity are compared with the ASAE recommendations.

Soil moisture distribution pattern:

The soil samples for moisture determination were collected at two intervals, *viz.*, 6 hrs. and 12 hrs. The moisture content of soil sample was determined by placing soil samples at 105^0 C and 24 hrs. in a oven by gravimetric method. Grids of 15 cm x 15 cm is plotted on the paper, emission point was considered at zero position and moisture content of different location is placed as specified point, soil samples for moisture determination is taken from only and side of the emission source and same reading is taken into account on the another side of the emission point. By considering the moisture content of the soil, moisture contours are potted for 6 hrs. and 12 hrs.

Relation between observed wetted front width and depth:

An average discharge rate of 0.6 lit/hr is allowed to flow through the lateral for determination of the wetting front width and depth. Eight numbers of drippers, having discharge of 0.6 lit/hr were selected in the same field. The time interval kept for measurement of wetted width and depth was 1.5 hr. The reading of wetted width and depth was taken at 1.5, 3, 4.5, 6, 7.5, 9, 10 hr on the each dripper. The reading of wetted depth was taken at emission point of each dripper and for wetted diameter of wetting front was taken at 4 points and average width was calculated. For establishing the relationship between observed wetted front width and depth four mathematical relationship were selected which is mentioned in Table A.

Table A : Model constants for wetted front depths

Model No.	Model name	Model
1.	Linear fit	$Y = a + bt$
2.	Logarithmic model	$Y= a + b \text{ In } t$
3.	Exponential fit	$y = ae^{bt}$
4.	Polynomial model	$Y = ax^n + bx + c$

The data were fixed in this equation and constant were work out using "EXCEL" computer software

Relationship between wetted front position and time:

After measuring the advancement of horizontal and vertical movement of water. The relationship between the maximum horizontal diameters of wetting front with the elapse time was determined by plotting the graph of average wetted width verses elapsed time. The same relationship was determined for depth and elapsed time by plotting the graph of wetted depth verses elapsed time.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Emission uniformity :

Keller and Karmeli (1974) suggested two parameters for evaluation of emission uniformity "EU'' which is a measure denoting the degree of uniformity of water application to the field.

They are EU_f and EU_a

$$EU_f = \left[\frac{q_n}{q_a}\right] x100$$

$$EU_a = 100\left[\frac{Q_{min}}{Q_{avg}} + \frac{Q_{avg}}{Q_x}\right] x \frac{1}{2}$$

where,

EU_f is field emission uniformity;

EU_a is absolute emission uniformity;

q_n is The average lowest ¼ of the emitter flow rate,L/h;

q_a is the average of all emitter flow rates,L/h;

q_x is the average of the highest 1/8 of the emitter flow rate,L/h.

The hydraulic characteristics of the gravity drip irrigation system were estimated by using above equations. The calculated average value of co-efficient of manufactures variation was 0.071 and as per ASAE interpretation the manufacturing qualities were average for the system. Using the value of manufactures co-efficient of variation the emission uniformity was calculated by equation given by Christiansen (1942). The emission uniformity for gravity inline drip irrigation system was found to be 85 per cent. The value of emission uniformity was found to be good as per ASAE Interpretation.

Soil moisture distribution pattern:

Gravity inline drip irrigation system was operated for different hours for determination of vertical and lateral movement of the water into the soil also the physico-chemical properties of soil and water and moisture content of the soil are determined by standard method. The texture of soil is sandy loam having average depth about 70 to 80 cm. The bulk density of soil is about 1.2 g /cc. and field capacity moisture content of soil was about 19.24 per cent. Data of initial moisture content of the soil at various depths and moisture content of soil after

Table 1 : Observed soil moisture status at different depths of soil

Sr. No.	Grid point (cm)	Soil moisture content (%) 6 hrs.	Grid point (cm)	Soil moisture content (%) 12 hrs.
1.	0-0	20.9	0-0	21.0
2.	0-15	22.0	0-15	22.2
3.	0-30	22.1	0-30	22.5
4.	0-45	21.2	0-45	21.8
5.	0-60	20.6	0-60	20.6
6.	0-75	----	0-75	20.3
7.	15-0	19.1	15-0	20
8.	15-15	20.1	15-15	20.5
9.	15-30	20.3	15-30	20.9
10.	15-45	19.95	15-45	20.45
11.	15-60	19.70	15-60	20.2
12.	0-23	15.7	15-75	20.17
13.	23-15	17.4	25-0	19.93
14.	23-30	16.8	23-325-150	19.85
15.	23-45	16.2	23-4525-30	20.1
16.	----	----	25-45	19.75

irrigating the soil for 6 hrs. and 12 hrs. are presented in Table 1.

From the Table 1, it is observed that vertical movement of water was more dominant than lateral movement in case of gravel sandy loam laterirtic soil. By making the use of moisture content data at various depths given, it is observed that the movement of moisture contour is faster in 6 hrs. as compared to 12 hrs.

Measurement of wetting front advance :

Variation of wetted front radius on soil surface and wetted front depth below the soil surface with time using inline drippers in gravel sandy soil are presented in Table 2. It may be seen from Table 2 that, the lateral movement of water was 20.1 cm for 6 hr and 25.2 cm for 12 hr. Vertical movement water for 6 hr was 45 cm and 75 cm for 12 hr.

Development of relationship between wetted front position and time:

The readings of wetted front widths and depth were taken. The model constants have been determined for wetted front depths and width and it is shown in Table 3. From the Table 3 and 4, it was observed that logarithmic model is suitable because its simplicity and value of R^2 as 0.9672, hence, it was selected for determination of vertical and lateral movement of water relationship. Vertical movement vs. lateral movement is seen that wetted front advancement in vertical direction in gravel sandy loam soil under 0.6 lit/hr discharge rates varies polynomial with the horizontal movement.

Wetting patterns are characterized by the radial distance of the wetting front and the depth of wetting from the point source (emitter). Illustrate surface wetted radius and vertical wetted depth, as a function of time for different application rates with the sandy soil. It is

Table 2 : Measured value of wetted front radius and depth at different time interval

Time	Depth (cm)	Average radius (cm)
0	0	0
1.5	12.5	9.15
3	25.5	13.85
4.5	36.11	17
6	45	20.1
7.5	53.5	21.55
9	61.7	22.75
10.5	68.7	24.1
12	75	25.2

Table 3 : Model constants for wetted front depths

Model No.	Model name	Model	R^2 values
1.	Linear fit	Y= a + bt	0.9865
2.	Logarithmic Model	Y= a + b In t	0.9641
3.	Exponential fit	$y = ae^{bt}$	0.9756
4.	Polynomial model	$Y = ax^n + bx + c$	0.9996

Table 4 : Model constants for wetted front widths

Model No.	Model name	Model	R^2 values
1.	Linear fit	Y= a + bt	0.8687
2.	Logarithmic model	Y= a + b In t	0.9947
3.	Exponential fit	$y = ae^{bt}$	0.9741
4.	Polynomial model	$Y = ax^n + bx + c$	0.9816

apparent that a greater application rate allows water to move faster both vertically and horizontally.

From the observations and Table 3 and 4 of elapsed time vs. advancement of wetted front, it was seen that for both vertical and horizontal movement of water logarithmic model is best suited and having the R^2-value as 0.9641 and 0.9947, respectively. Similar work related to the present investigation was also carried out by Singh *et al.* (1977); Sivanappan *et al.* (1976); Solomon (1979) and Wu and Gitlin (1974; 1975 and 1979).

Conclusion:

The study led to the following conclusions.

The co-efficient of manufactures variation of the emitters was to be 0.071, which was average as compared to the ASAE interpretation for the tested emitters and good performance was observed on the basis of manufactures co-efficient of variation.

The emission uniformity of the system was computed as 85 per cent as per standard procedure suggested by Christiansen (1942). According to the ASAE interpretation the emission uniformity was good for tested emitters.

The vertical and radial movement of moisture was observed upto 60, 46 cm for 6 hrs. and 80, 50 cm for 12 hrs., respectively. Which shows that the movement of moisture contour was faster in 6 hrs. as compared to 12 hrs. The moisture distribution pattern in gravel sandy loam soil shows that the vertical movement of water is predominant than the lateral movement.

The relationship between the wetted depth and time was found to be logarithmic having the value of R^2 as 0.9641. Also logarithmic model was found to be suitable for the relationship between wetted widths with time having the value of R^2 as 0.9947. From the observations it was seen that wetted radius and vertical wetted depth, as a function of time for different application rates with the sandy soil .It is apparent that a greater application rate allows water to move faster both vertically and horizontally.

The logarithmic relationship was found between wetted depths with wetted radius, which shows that vertical movement was greater as compared to the horizontal movement. The observed value of R^2 was found to be 0.9672.

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