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Feasibility study of gravity drip irrigation for small scale farmers

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■ **ABSTRACT :** Gravity fed drip irrigation techniques have been used in the small agricultural production as an advanced water saving irrigation method in recent times. However advantageous this method, there are still some difficulties in projecting the efficiency of such systems. Most especially, feasibility study of gravity drip irrigation for small scale farmers is very important in order to set up an efficient irrigation system. This study is focused to test the feasibility of the drip irrigation the experiment was run and Uniformity co-efficient and Distribution uniformity. In the study, the discharge of emitters at 1.0 m and 0.5 m emitter spacing and 1.0 m lateral spacing and for four irrigation durations (15 minutes, 30 minutes, 60 minutes and 120 minutes) was measured. The results clearly indicates that the selected emitters of 4 LPH rated discharge and 2.0 kg/cm^2 pressure when used under gravity drip irrigation and at about 0.5-0.8 kg/cm^2 pressure, discharges between 1.8-2.5 LPH. 6. The gravity drip irrigation can meet the water requirement of vegetable crops with acceptable UC and DU and can be a better solution for small scale farmers of the region in order to save the scarce fresh water resources.

■ **KEY WORDS :** Gravity drip irrigation, Irrigation durations, Uniformity co-efficient, Distribution uniformity

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Water is essential for socio-economic development and for maintaining healthy ecosystems. As population increases and development calls for increased allocations of groundwater and surface water for the domestic, agricultural and industrial sectors, the pressure on water resources gets intensified, leading to tensions, conflicts among users, and excessive pressure on the environment. Scarcity often has its roots in water shortage, especially the arid and semiarid regions affected by droughts and wide climate variability, combined with population growth and economic development, where the problems of water scarcity are the most acute.

Water usage has been raising as much as more than twice the rate of population increase in the last century. The number of regions that suffered chronically short of water had increased. By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions. The situation will be exacerbated as rapidly growing urban areas place heavy pressure on neighboring water resources (Abdel Kawy and Abou El-Magd, 2012).

Although there are many sources of water consumption, irrigation remains the main water user on a global scale. However, there is an increasing pressure on agriculture to use water in a more efficient manner. On the contrary, irrigation is regarded as one of the main ways to increase food production and incomes. It is therefore crucial to enhanced water management to achieve both high water productivity and higher income (Abd El-Moez *et al.*, 2001).

Due to the limited water resources, which necessary for reclaiming more areas of desert to produce more food, some modern techniques must be used. Drip irrigation represents one of the most spreading systems in the new reclaimed areas. It has the ability to raise the efficiency of irrigation water, by reducing water losses via evaporation, saving water in root zone and hence preventing it from loss by percolation, and ultimately, increasing water use efficiency (Allen and Wanas, 1999). Abou-Hussein (2001) stated that drip irrigation efficiency ranged from 75-95 per cent compared to 25-50 per cent of surface irrigation and 75-80 per cent and 65-75 per cent of soiled set and portable sprinkler system, respectively. On the other hand, rationalization of irrigation water can be achieved using organic composts resulting from recycling farm wastes by a process known as composting. A study carried out by Acharya and Kapoor (2001) proved that sandy infertile soils can benefit from the addition of organic waste materials that increase soil organic matter content, decrease bulk density, and increase soil water retention of coarse soils.

The better soil and water management under drip irrigation system is an addition to organic soil conditioners, in combination with straw mulching and some developed agricultural methods. Allen and Rosenzweig (1991) indicated that incorporating organic manure with the soil in the surface soil layer passively affected on the aggregates formation and increased the tomato and potato yields under drip irrigation system. Also, the natural soil conditioners decreased the soil bulk density, infiltration rate and the hydraulic conductivity while increased the stable soil aggregates and total soil porosity in sandy soil. It was found that crop productivity and water use efficiency increased under drip irrigation, especially when the soil treated with organic amendments where hydro physical properties and nutrient status of the soil were improved (Aly *et al.*, 2011). With respect to mulching method, Anderson (1999) found that drip irrigation associated with mulching, led to the highest yield and the greatest water use efficiency. Wahba and Darwish (2008) reported evaporation and decreases the accumulation of salts in the root zone. Also, Wanas and abd-El-Moez (2005) reported that manure and surface mulching should be considered in land management and water conservation as they increase steady infiltration rates and amount of soil water stored in the soil and better drainage. Drip irrigation can help you use water efficiently. A well-designed drip irrigation system loses practically no water to runoff, deep percolation, or evaporation. Drip irrigation reduces water contact with crop leaves, stems, and fruit. Thus, conditions may be less favorable for disease development. Irrigation scheduling can be managed precisely to meet crop demands, holding the promise of increased yield and quality. Growers and irrigation professionals often refer to "subsurface drip irrigation," or SDI. When a drip tape or tube is buried below the soil surface, it is less vulnerable to damage during cultivation or weeding. With SDI, water use efficiency is maximized because there is even less evaporation or runoff.

A complete package of water regimes under drip irrigation, mulch and compost will save irrigation water under desert conditions and increase exported crops which represent a vital goal of this study which also can be used by small scale farmers. In 1999 the Rural Agricultural Development Authority introduced a drip irrigation system to small farmers that used gravity instead of a pump to provide the head (energy) for its operation. The objective was to enable farmers that have no natural source of water, those who were not connected to any public irrigation schemes and those who rely on rainfall, to produce mainly vegetables on a small scale. Agricultural chemicals can be applied more efficiently with drip irrigation. Since only the crop root zone is irrigated, nitrogen already in the soil is less subject to leaching losses, and applied fertilizer can be used more efficiently. In the case of insecticides, less product might be needed. Make sure the insecticide is labeled for application through drip irrigation.

■ METHODOLOGY

Gravity drip irrigation:

The concept of Gravity Drip Irrigation (GDI) has been developed with the purpose of providing the most economical solution for small scale growers. Proper operation of the system will result in higher yields, save water and energy and provide a simple fertilizer application method. This system is modular and highly cost effective.

Components of gravity drip irrigation system:

– *Water reservoir:* Capacity of at least one irrigation duration. The greater the capacity of the reservoir is proportional to how often it must be refilled. The reason to elevate the tank is that it adds pressure which needs to be kept consistent at the point where the drip lines are fed so that the water is distributed equally.

– Metallic Stand Structure to support the water reservoir

– Submain and lateral pipe lines of 12 mm diameter.

– Gate Valve and drip lines:

  - Gate valve should be placed between the reservoir pipes and the irrigation pipes.
  - Drip lines are the average lines and emitters that can be purchased at any garden supply store.

– Drippers were also used in the study which had a discharge rate of 4 litre/hour.

Installation of experimental setup:

To conduct the study on feasibility test of gravity drip irrigation for small agricultural lands, a lab experiment was conducted in Water Resource Engineering Laboratory of Department of Irrigation and Drainage Engineering, VIAET. The detail view of the experiment is shown in Fig. A. The water supply tank of 250 litres was connected with 16 mm diameter pipe and the water flow was regulated with the gate valve and pressure was measured with the pressure gauge of range 2 kg/ cm^{2}. Three lateral lines of 10 m each were connected with main line and two drippers spacing (0.5 m and 1.0 m) were considered for the study. The system was run for different time interval and emitters discharge were measured at regular interval of 15min, 30 min, 60 mins and 120 min intervals.

Hydraulic parameters of drip irrigation:

To test the feasibility of the drip irrigation the experiment was run and Uniformity co-efficient and Distribution uniformity was estimated. To calculate the UC and DU the catch cans were installed at every emitter along the all lateral lines and system was run for 15 min, 30 min, 60 min and 120 minutes of duration and collected water was measured with beaker and using the following formula the UC and DU was estimated.

Uniformity coefficient of drip irrigation (UC):

Christiansen's uniformity co-efficient (UC) is the most commonly used statistical method for evaluating drip system uniformity (Wanas, 2006). Christiansen's uniformity is defined as:

$$UC = 100\left[1 - \frac{\frac{1}{n\sum_{i=1}^{n}\left|q_i - \bar{q}\right|}}{\bar{q}}\right] \qquad \text{............ (1)}$$

where,

q_i = Discharge of single emitter.

$\bar{q}$ = Average discharge of the emitter.

n= Number of emitters

Fig. A : Typical layout of a gravity drip irrigation system

Distribution Uniformity (DU):

Kruse (1978), calculated using the equation:

$$DC = 100\,\frac{q1_q}{\bar{q}} \qquad \text{............ (2)}$$

where,

$q1_q$ = Average Low Quarter Depth of application.

$\bar{q}$ = Overall Average Depth of application.

Statistical analysis:

To test the feasibility of the gravity drip irrigation the results of the experiments were tested statistically. Uniformity Co-efficients and Distribution Uniformity were checked statistically using the results of the ANOVA test.

Results and Discussion

The result related to the experiment conducted on the "Feasibility study of Gravity drip irrigation for small scale farmers" are given in the following heads.

Dimensions and specifications of various experimental parameter:

Following were the dimensions and specifications of the various components of the experimental setup used for the study

– The capacity of the water tank used =200 litres

– Distance of lateral lines from the bottom of the tank = 141 cm = 1.41 m

– Discharge of the drippers used = 4 LpH

– Measured working pressure at the inlet of the inlet of the Lateral line is 0.9 kg/cm^2.

– The rated pressure of the drippers selected is 1.5-2.0 kg/cm^2.

Assumption of the study:

From the literature reviewed it was found that generally gravity drip irrigation is working at very low pressure *i.e.* 0.1- 1.0 kg/cm^2 as the pressure is only created by water stored in the reservoir and the height of the reservoir. In many countries, the irrigation companies are manufacturing the special emitters working at very low pressure in gravity drip irrigation. Since in Allahabad region this type of emitters was not available, the present study was planned to test the feasibility of gravity drip irrigation with existing common 4 LPH drippers. Thus, the study was conducted with the constraint that the selected drippers of 4LPH can be used under low pressure working condition.

Emitter discharge along the lateral for different irrigation durations at 1.0 m Emitter and 1.0 m Lateral Spacing:

The discharge of emitters at 1.0 m and 0.5 m emitter spacing and 1.0 m lateral spacing and for four irrigation durations (15 minutes, 30 minutes, 60 minutes and 120 minutes) was measured and results are given on Table 1 to Table 8. The results clearly indicates that the selected emitters of 4 LPH rated discharge and 2.0 kg/cm^2 pressure when used under gravity drip irrigation and at about 0.5-0.8 kg/cm^2 pressure, discharges between 1.8-2.5 LPH.

Table 1 : Discharge of Emitters (Liters) when installed at 1.0 m dripper spacing and 1 m lateral spacing after 15 minutes of irrigation duration

Distance of dripper on lateral line (m)	Dripper discharge (Liters)			
	Lateral 1 (R_1)	Lateral 2 (R_2)	Lateral 3 (R_3)	Mean
1	0.49	0.56	0.56	0.63
2	0.81	0.56	0.68	0.66
3	0.89	0.44	0.66	0.65
4	0.54	0.55	0.53	0.51
5	0.56	0.58	0.53	0.46
6	0.56	0.70	0.58	0.49
7	0.54	0.55	0.58	0.64
8	0.59	0.49	0.54	0.54
C.D. (P=0.05)	0.089			

Table 2 : Discharge of Emitters (Liters) when installed at 1.0 m dripper spacing and 1 m lateral spacing after 30 minutes of irrigation duration

Distance of drippers on lateral line (m)	Dripper discharge (Liters)			
	Lateral 1 (R_1)	Lateral 2 (R_2)	Lateral 3 (R_3)	Mean
1	1.24	0.94	1.10	1.09
2	1.26	0.98	1.12	1.12
3	1.24	1.52	0.90	1.22
4	1.00	1.04	1.10	1.05
5	0.92	1.12	1.18	1.07
6	0.96	1.06	1.04	1.02
7	1.26	1.06	1.12	1.15
8	1.08	1.20	1.00	1.09
C.D. (P=0.05)	0.13			

Table 3 : Discharge of Emitters (Liters) when installed at 1.0 m dripper spacing and 1 m lateral spacing after 60 minutes of irrigation duration

Distance of drippers on lateral line (m)	Dripper discharge (Liters) Lateral 1 (R_1)	Lateral 2 (R_2)	Lateral 3 (R_3)	Mean
1	2.44	2.36	2.12	2.31
2	2.48	1.92	2.20	2.20
3	2.36	2.88	1.80	2.35
4	2.00	2.00	2.08	2.03
5	1.80	2.20	2.48	2.16
6	1.88	2.08	2.08	2.01
7	2.48	2.08	2.20	2.25
8	2.12	2.84	1.96	2.31
C.D. (P=0.05)		0.263		

Table 4 : Discharge of Emitters (Liters) when installed at 1.0 m dripper spacing and 1 m lateral spacing after 120 minutes of irrigation duration

Distance of drippers on lateral line (m)	Dripper discharge (Liters) Lateral 1 (R_1)	Lateral 2 (R_2)	Lateral 3 (R_3)	Mean
1	4.80	4.56	4.08	4.48
2	4.64	3.76	4.24	4.27
3	4.64	5.60	3.44	4.56
4	3.84	3.92	3.92	3.89
5	3.52	4.16	4.72	4.13
6	3.60	4.08	4.00	3.89
7	4.72	4.08	4.24	4.35
8	2.12	2.84	1.96	2.31
C.D. (P=0.05)		0.440		

Table 5 : Discharge of Emitters (Liters) when installed at 0.5 m dripper spacing and 1 m lateral spacing after 15 minutes of irrigation duration

Distance of drippers on lateral lines (m)	Dripper discharge (LpH) Lateral 1 (R_1)	Lateral 2 (R_2)	Lateral 3 (R_3)	Mean
1	0.63	0.52	0.59	0.58
2	0.60	0.55	0.52	0.56
3	0.58	0.46	0.50	0.51
4	0.55	0.47	0.53	0.52
5	0.61	0.69	0.52	0.61
6	0.58	0.66	0.44	0.56
7	0.54	0.62	0.52	0.56
8	0.50	0.50	0.50	0.50
9	0.50	0.66	0.51	0.56
10	0.44	0.53	0.57	0.51
11	0.50	0.52	0.47	0.50
12	0.46	0.52	0.45	0.48
13	0.49	0.58	0.48	0.52
14	0.52	0.47	0.50	0.50
15	0.57	0.49	0.44	0.50
16	0.49	0.38	0.44	0.44
C.D. (P=0.05)			0.045	

Table 6 : Discharge of Emitters (Liters) when installed at 0.5 m dripper spacing and 1 m lateral spacing after 30 minutes of irrigation duration

Distance of drippers on lateral lines (m)	Dripper Discharge (LpH)			
	Lateral 1 (R_1)	Lateral 2 (R_2)	Lateral 3 (R_3)	Mean
1	1.26	1.04	1.18	1.16
2	1.20	1.10	1.04	1.11
3	1.16	0.92	1.00	1.03
4	1.10	0.94	1.06	1.03
5	1.22	1.38	1.04	1.21
6	1.16	1.32	0.88	1.12
7	1.08	1.24	1.04	1.12
8	1.00	1.00	1.00	1.00
9	1.00	1.32	1.02	1.11
10	0.88	1.06	1.14	1.03
11	1.00	1.04	0.94	0.99
12	0.92	1.04	0.90	0.95
13	0.98	1.16	0.96	1.03
14	1.04	0.94	1.00	0.99
15	1.14	0.98	0.88	1.00
16	0.98	0.76	0.88	0.87
C.D. (P=0.05)			0.095	

Table 7 : Discharge of Emitters (Liters) when installed at 0.5 m dripper spacing and 1 m lateral spacing after 60 minutes of irrigation duration

Distance of drippers on lateral lines (m)	Dripper Discharge (LpH)			
	Lateral 1 (R_1)	Lateral 2 (R_2)	Lateral 3 (R_3)	Mean
1	2.52	2.08	2.36	2.32
2	2.40	2.20	2.08	2.23
3	2.32	1.84	2.00	2.05
4	2.20	1.88	2.12	2.07
5	2.44	2.76	2.08	2.43
6	2.32	2.64	1.76	2.24
7	2.16	2.40	2.08	2.21
8	2.00	2.00	2.00	2.00
9	2.00	2.64	2.04	2.23
10	1.76	2.12	2.28	2.05
11	2.00	2.08	1.88	1.99
12	1.84	2.08	1.80	1.91
13	1.96	2.32	1.92	2.07
14	2.08	1.88	2.00	1.99
15	2.28	1.96	1.76	2.00
16	1.96	1.52	1.76	1.75
C.D. (P=0.05)			0.188	

Uniformity co-efficient and distribution uniformity for various irrigation duration at 1.0 m emitter spacing:

The uniformity co-efficient and distribution uniformity was estimated as described in article 2.4.1 and 2.4.2. The graphical representation of results of uniformity co-efficient and distribution uniformity are given in Fig. 1-3. Both the figures clearly indicated that the highest UC and DU was observed for 120 minutes duration which is 91 per cent and 87.92 per cent, respectively. These values indicate that if the emitters of 4LPH discharge are used in field as a gravity drip

Table 8 : Discharge of Emitters (Liters) when installed at 0.5 m dripper spacing and 1 m lateral spacing after 120 minutes of irrigation duration

Distance of drippers on lateral lines (m)	Dripper Discharge (LpH)			
	Lateral 1 (R_1)	Lateral 2 (R_2)	Lateral 3 (R_3)	Mean
1	5.04	4.16	4.72	4.64
2	4.80	4.40	4.16	4.45
3	4.64	3.68	4.00	4.11
4	4.40	3.76	4.24	4.13
5	4.88	5.52	4.16	4.85
6	4.64	5.28	3.52	4.48
7	4.32	4.80	4.16	4.43
8	4.00	4.00	4.00	4.00
9	4.00	5.28	4.08	4.45
10	3.52	4.24	4.56	4.11
11	4.00	4.16	3.76	3.97
12	3.68	4.16	3.60	3.81
13	3.92	4.64	3.84	4.13
14	4.16	3.76	4.00	3.97
15	4.56	3.92	3.52	4.00
16	3.92	3.04	3.52	3.49
C.D. (P=0.05)			0.376	

irrigation with low pressure range of 0.1-0.8 kg/cm^2, although it will discharge half of the rated discharge but that will be distributed very evenly with DU of 88 per cent and UC of 90.95 per cent. These results show that the emitters with rated discharge of 4 LPH can be used with discharge of 2.5 LPH at 0.5- 0.8 kg/cm^2 pressure created by installing the 250-litre water tank at 1.4 - 2.0 m height.

Analysis of hydraulic parameters of gravity drip irrigation:

Since the small-scale farmers of the region have small land holdings and economic conditions of the farmers are also not very strong, it is difficult for them to bear the initial high cost of the drip irrigation. Sometimes small farmers are also not having the proper energy source for the whole duration of irrigation and thus the drip irrigation adoption have a major constraint. The emitters of 4 LPH were tested for the lateral length of 10 m each with gravity drip irrigation at under pressure conditions, still it provide the average discharge of 2.5 LPH with Uniformity co-efficient of 91 per cent and distribution Uniformity of 87.92 per cent. The used drippers were designed for pressure range of 1.5-2.0 kg/cm^2 whereas the working pressure available was 0.9 kg/cm^2. From the study, if the manufacturers will manufacture the drippers at for the pressure range of 0.8-1.5 kg/cm^2, the higher Uniformity coefficient and Distribution Uniformity can be obtained and cost of gravity drip irrigation system can be reduced thus it can raise the wider acceptability of the system among the farming community of the region which has comparatively lower socio-economic conditions and power availability for farming activities. The gravity drip irrigation can meet the water requirement of vegetable crops with acceptable UC and DU and can be a better

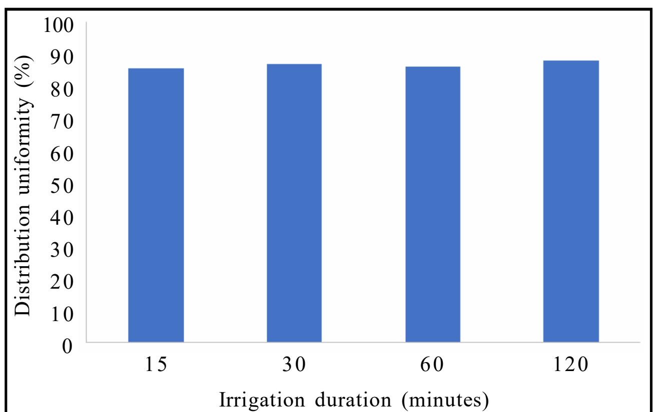

Fig. 1 : Distribution Uniformity (%) of gravity drip irrigation for various irrigation durations at 1.0 m emitter spacing

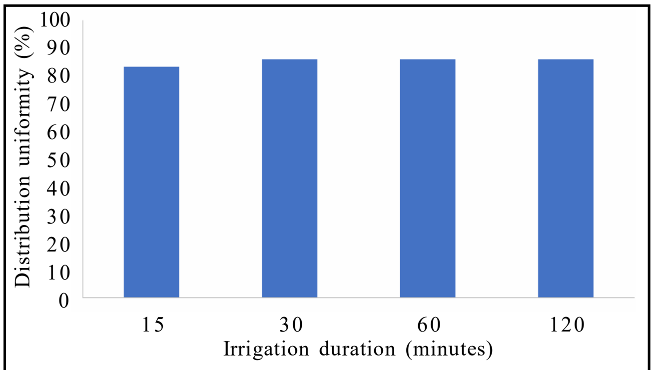

Fig. 2 : Distribution Uniformity (%) of gravity drip irrigation for various irrigation durations at 0.5 m emitter spacing

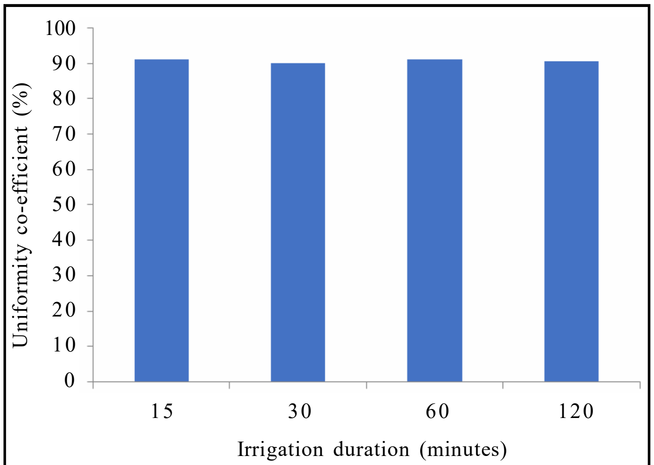

Fig. 3 : Christianson Uniformity Co-efficient (%) of gravity drip irrigation for various irrigation durations at 0.5 m emitter spacing

solution for small scale farmers of the region in order to save the scarce fresh water resources.

Conclusion:

Since the small-scale farmers of the region have small land holdings and economic conditions of the farmers are also not very strong, it is difficult for them to bear the initial high cost of the drip irrigation. Sometimes small farmers are also not having the proper energy source for the duration of irrigation and thus the drip irrigation adoption have a major constraint. The emitters of 4 LPH were tested for the lateral length of 10 m each with gravity drip irrigation at under pressure conditions, still it provide the average discharge of 2.5 LPH with Uniformity coefficient of 91 per cent and distribution Uniformity of 87.92 per cent. The used drippers were designed for pressure range of 1.5-2.0 kg/cm^2 whereas the working pressure available was 0.9 kg/cm^2. From the study, it is clear that if the manufacturers will manufacture the drippers at for the pressure range of 0.5-1.0 kg/cm^2, the higher Uniformity coefficient and Distribution Uniformity can be can be obtained and cost of the gravity drip irrigation can be reduced significantly. The gravity drip irrigation can meet the water requirement of vegetable crops with acceptable UC and DU and can be a better solution for small scale farmers of the region in order to save the scarce fresh water resources.

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