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Technical Evaluation of Low-Head Drip Irrigation System

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Abstract:
The purpose of this study was to evaluate the effectiveness of the low-head drip irrigation system in Bangladesh. The research was conducted at the Department of Irrigation and Water Management's Hydraulic Lab at Bangladesh Agricultural University. The experimental setup consisted of varying the water supply head from 0.91–1.83 m and placing a lateral drip pipe of 15.24 m on horizontal tables. Catch cans were placed beneath the emitter tubes to collect the emitted water, and the water container was placed on a wooden table, whose height was altered to create different supply heads. The variation in water distribution was demonstrated by emission uniformity (EU) and flow variation (FV) along the drip line. This study discusses how the EU and FV values change with varying water head and lateral length, demonstrating that these factors impact computed results. The results show that the EU increased with an increase in supply head, while the FV decreased with an increase in the head. The bucket drip irrigation system was found to have EU values ranging from 33–42% and FV values from 44–51% under the fluctuating head ranging between 0.91–1.83 m, indicating that the method is not only incredibly inefficient but also expensive.

Keywords Low-head, Drip irrigation, Emission Uniformity, and Flow Variation.

INTRODUCTION

Water is an essential resource, but as the global environment and climate have changed, water scarcity issues have gained widespread attention (Zhao et al., 2022). Irrigation is an essential type of water management for agricultural production because it provides crops with water to avoid famine. In Bangladesh, approximately 80-85% of the population lives in rural areas, and 80% is employed in agriculture, with irrigation being a valuable but scarce resource (Zaher & Mazid, 1992). Three main irrigation methods are used in Bangladesh: strip, furrow, and flooding. However, research shows that these methods have the disadvantage of substantial water losses due to excessive water intake, seepage, deep percolation, and evaporation (Hoque, 2017; Teshome et al., 2018). Studies have shown that better yields result from evenly applying water to the soil's field capacity by encouraging greater nutrient and water uptake by plants (de Oliveira et al., 2015). Therefore, drip irrigation is Bangladesh's most promising method for dryland horticultural crops. Kulecho and Weatherhead (2005) noted that some African countries promote low-cost drip irrigation for small-scale farming. Using saline water for irrigation, according to Karlberg (2003), boosts water productivity by freeing fresh water for other uses, as demonstrated by the use of two drip systems with varying emitter discharge rates (0.2 and 2.5 l h^{-1}) to irrigate tomatoes with water of three different salinity levels. (Ngigi, 2008) stated that low-head drip technology is proving successful in Kenya. This technology consists of a water supply source (20-liter bucket, 40-100-liter jerrican, or 200-liter drum) placed 0.5-1.0 m above crops planted along laterals at specified emitter spacing. (Ngigi, 2008) also noted that most vegetables in bucket drip irrigation have a 3-month investment cost recovery. Thus, it is a profitable venture, especially for small-scale farmers. Low-cost bucket drip systems by ARFA Engineering are used in some Bangladeshi regions. However, the emitter discharge effect of lateral length, land slope, and water supply is yet to be examined. Thus, research is needed to upgrade the existing system and design or develop a low-head drip irrigation system that utilizes native resources and skills. This study aims to assess the technical performance of the ARFA drip irrigation system. Specifically, it will establish an experimental framework, measure the effect of the water supply head on emitter discharge, and analyze the emission uniformity along the drip line.

MATERIAL AND METHODS

Experiments were conducted at the Hydraulic Lab, Department of Irrigation and Water Management, Bangladesh Agricultural University (BAU), Mymensingh.

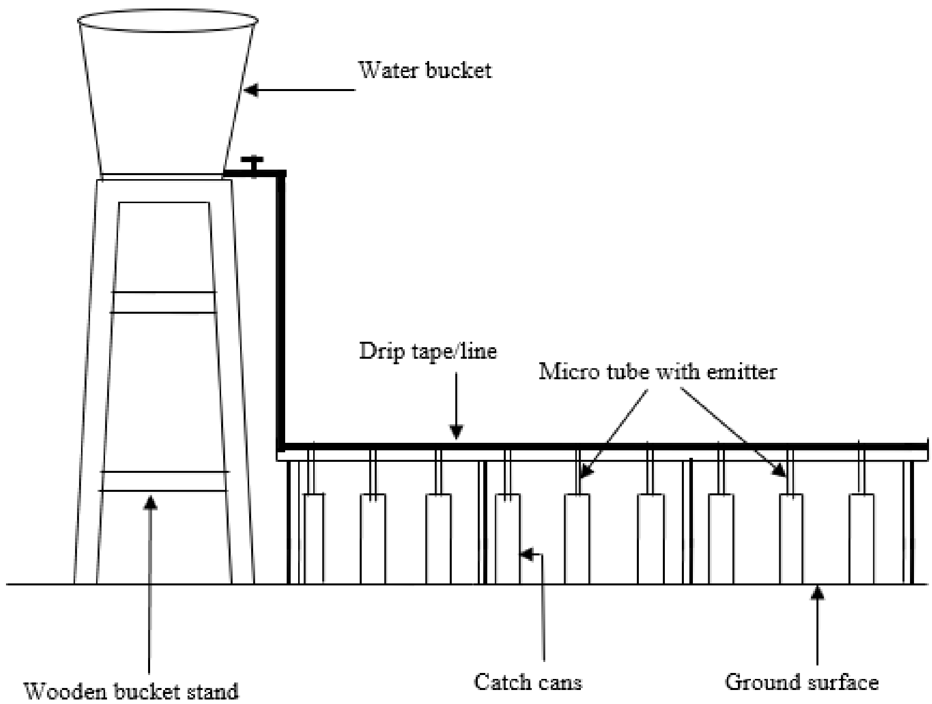

Figure 1: Side view of the experimental layout used for evaluating the performance of the drip system.

The arrangement in the lab, where supporting tables were positioned longitudinally to support the drip line, is shown in Figure 1. A PVC bucket used as a water source was set down on a tall table, the height of which was adjusted for different supply heads. The water was allowed to flow through the lateral line 15.24 m long, 1 mm thick, with an internal diameter of 16 mm, and then through drip lines fitted with micro tubes 5 cm long and an internal diameter of 1.2 mm as emitters. To catch the emitters discharges, catch cans were positioned beneath the emitters.

The materials and equipment used for the study include:

1. A PVC bucket with a hole at the bottom

2. A simple support
3. Water outlet fitting and filter for keeping sand and silt from blocking the
4. 1 mm thick plastic tube as laterals
5. 2 mm by 5 cm micro-plastic tubes as emitters
6. Catch cans to catch water from emitters
7. Stopwatch to record the time of water collection from emitters
8. 250 ml graduated cylinders to measure the volume of water collected from emitters.

Discharge Measurement

The average discharge rate was determined using a graduated measuring cylinder, catch cans, and a stopwatch. After lifting the model for 15 minutes, the amount of water collected in catch cans was measured. The test was conducted three times to determine the average capacity in liters. To calculate the discharge (q) l/sec, divide the average volume by the passing time (equation. 3.1) (Ahmed et al., 2020).

$$q = \frac{\mathrm{V}}{t * 1000} \qquad 3.1$$

Where,

q = Discharge (L/sec)
V = Volume collected (ml)
t = Time taken (sec)

Coefficient of Variation (CV)

The following equation 3.2 was used to calculate the emitter flow coefficient from discharge measurements of the plastic tubes:

$$CV = \frac{(q_1^2 + q_2^2 + \cdots \ldots\ldots\ldots\ldots q_n^2 - nq^2)^{\frac{1}{2}}}{q(n-1)^{\frac{1}{2}}} \qquad 3.2$$

Where,

CV = Coefficient of variation of emission device
q1, q2…qn = Discharge of emission devices
q = Average discharge of emission devices tested
n = Number of emission devices tested

Emission Uniformity (EU)

Emission Uniformity of the system was calculated using the following equation 3.3

$$EU = \frac{\mathrm{Qmin}}{Qmean} (1 - 1.27\ \mathrm{CV})\ 100 \qquad 3.3$$

Where,

EU = Design emission uniformity (%)
Qmin = the lowest emitter discharge (average of 25% of emitters with lowest discharge)
Qmean = average emitter discharge (the equivalent of 50% of the probability distribution)

Flow Variation (FV)

Flow variation of system was calculated using the equation 3.4

$$FV = 1 - \frac{Qmin}{Qmax} \quad \text{.......... 3.4}$$

Where,

Qmax = maximum emitter discharge (average of 25% of emitters with highest discharge)

Qmin = the lowest emitter discharge (average of 25% of emitters with lowest discharge)

The equations are adapted from (IGBOJIONU et al., 2021)

The EU and FV are sensitive to computational errors related to extreme values of the emitter discharges. Therefore, average emitter discharge of the lower and upper quartiles was adopted for Qmin and Qmax, respectively, while Qmedian was adopted for Qmean. The general performances of evaluation criteria for EU values are: ≥90%, excellent: 80–90%, good; 70–80%, fair; and <70%, poor. The general criteria for FV values are: ≤10%, desirable; 10–20%, acceptable; and >20%, unacceptable (Riza et al., 2016).

RESULTS

The emitter discharge distribution pattern under different supply heads has been given in Table 1 and Table 2. The values of EU and FV have been presented in Table 3 and Figure 3 represents the variation of EU with the water supply head. It appears from Table 1 and Figure 2 that emitter discharge gradually decreases with the increase of the distance of the lateral pipe.

Table 1: Emitter discharge for different supply heads and lateral length

Emitter position	Lateral length, m	Emitter discharge					
		(ml)			(lit /sec)		
		at 0.91 m head	*at 1.37 m head*	*at 1.83 m head*	*at 0.91 m head*	*at 1.37 m head*	*at 1.83m head*
1	0.15	148	126	170	0.000822	0.0007	0.000944
2	0.61	84	95	97	0.000467	0.000528	0.000539
3	1.07	52	82	84	0.000289	0.000456	0.000467
4	1.52	54	65	80	0.0003	0.000361	0.000444
5	1.98	46	75	79	0.000256	0.000417	0.000439
6	2.44	55	49	61	0.000306	0.000272	0.000339
7	2.90	73	56	84	0.000406	0.000311	0.000467
8	3.35	42	67	79	0.000233	0.000372	0.000439
9	3.81	66	78	93	0.000367	0.000433	0.000517
10	4.27	56	65	66	0.000311	0.000361	0.000367
11	4.73	59	58	55	0.000328	0.000322	0.000306
12	5.18	63	61	66	0.00035	0.000339	0.000367
13	5.64	61	57	54	0.000339	0.000317	0.0003
14	6.10	65	72	75	0.000361	0.0004	0.000417
15	6.55	46	61	67	0.000256	0.000339	0.000372
16	7.01	66	47	90	0.000367	0.000261	0.0005
17	7.47	42	42	73	0.000233	0.000233	0.000406
18	7.93	39	46	76	0.000217	0.000256	0.000422
19	8.38		84	61		0.000467	0.000339
20	8.84		75	67		0.000417	0.000372
21	9.30		63	65		0.00035	0.000361
22	9.76		54	65		0.0003	0.000361

23	10.21		49	81		0.000272	0.00045
24	10.67		38	46		0.000211	0.000256
25	11.13		61	53		0.000339	0.000294
26	11.59		55	61		0.000306	0.000339
27	12.04		46	68		0.000256	0.000378
28	12.50		50	51		0.000278	0.000283
29	12.96		51	43		0.000283	0.000239
30	13.41		52	58		0.000289	0.000322
		$\bar{q}$=62.06	$\bar{q}$=62.67	$\bar{q}$=72.27	$\bar{q}$=0.000345	$\bar{q}$=0.000348	$\bar{q}$=0.000401

Table 2: Effect of water supply head on lateral length

Water head, m	Slope (%)	Length, m	Comments
0.91	0	7.93	No flow after 8m
1.37	0	13.41	Medium flow
1.83	0	13.41	Higher flow than before

Table 3: EU (%) and FV (%) for different supply water heads

Supply head, m	CV	Q_{min} (ml)	Q_{max} (ml)	Q_{mean} (ml)	FV (%)	EU (%)
0.91	0.391	43.00	87.40	65.20	50.82	33.15
1.37	0.289	47.50	85.88	66.69	44.65	45.04
1.83	0.322	54.50	97.38	75.94	43.99	42.44

Effect of Supply Head on Emitter Discharge Along the Lateral Length

Figure 2 shows the effect of the water supply head on emitter discharge along the lateral length. Based on this graph, it can be seen that emitter discharge rises as supply head increases and eventually falls as lateral length grows.

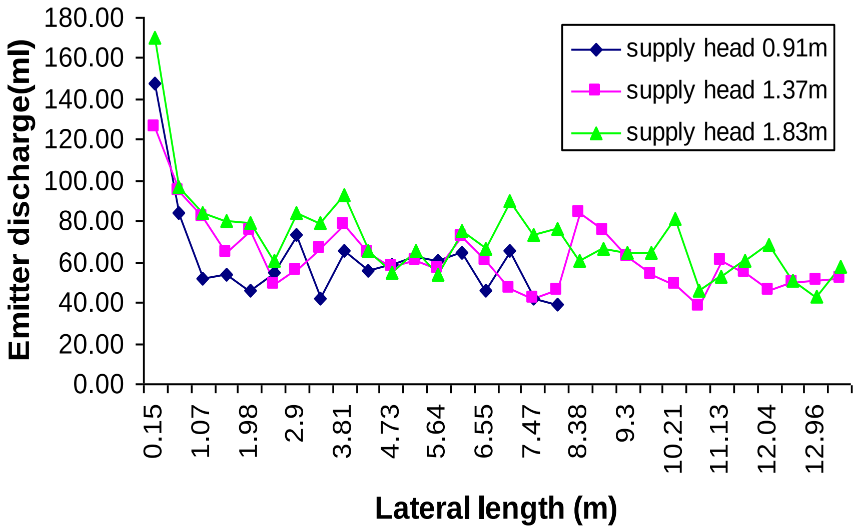

Figure 2: Effect of water head on emitter discharge along the length of lateral

Effect of Supply Head on Water Distribution Uniformity

The EU's values improve (from 33–42 %) with an increase in supply head from 0.91–1.83 m but not significant (Figure 3). FV increases with a decrease in the head (Figure 4). The experiment was conducted on a flat slope (0% slope), and it is expected that the EU will decrease further with an increase in land slope. The EU values under different water supply heads, as shown in Table 3, varied from about 33%–42%, indicating the very poor (<70%) performances of the ARFA bucket drip system. The system may be suitable for very small vegetable plots. The drip openings and sizes of micro-tubes should be redesigned along the drip lines to improve the EU. Almost Similar findings is reported by (IGBOJIONU et al., 2021), where the FV was 8%, the CV of the emitter discharge was 0.02, the uniformity coefficient (UC) was 97%, and the EU was 73%. The results show that the system is effective and that farmers can use it to meet the demand for vegetables during the dry season. Researches suggesting that the bucket drip irrigation system saves water by maintaining a high uniform application of irrigation and wetted diameter (Fandika et al., 2012). However low head drip irrigation resulted satisfactory result than high head system (Ngigi, 2008).

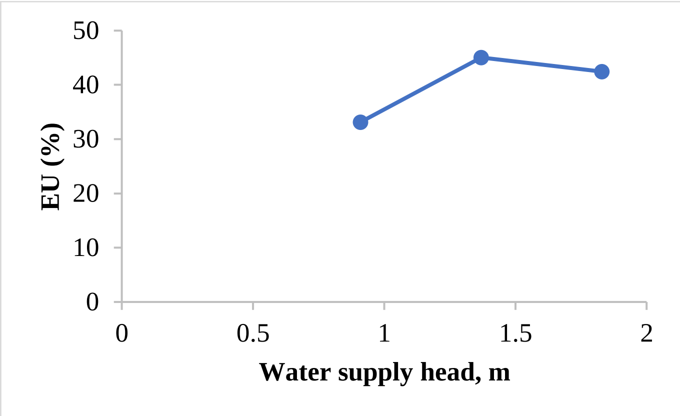

Figure 3: Variation of EU with water supply heads at 0% slope

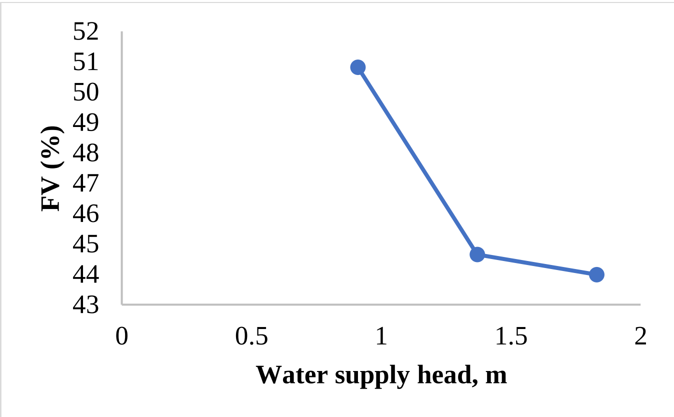

Figure 4: Variation of FV with water supply heads at 0% slope

DISCUSSION

A drip irrigation system is made to evenly and precisely distribute a specified amount of water near the plant. The results and findings suggest that the Emission Uniformity (EU) values for water supply heads of 0.91m, 1.37m, and 1.83m were 33.15%, 45.04%, and 42.45%, respectively. This indicates poor performance of the system, making it unsuitable for crop irrigation, although it may be suitable for small plots. The Flow Variation (FV) values were 50.82%, 44.65%, and 43.99%, indicating inefficiency. Almost Similar findings is reported by (IGBOJIONU et al., 2021), where the FV was 8%, the CV of the emitter discharge was 0.02, the uniformity coefficient (UC) was 97%, and the EU was 73%. The results show that the system is effective and that farmers can use it to meet the demand for vegetables during the dry season. Researches suggesting that the bucket drip irrigation system saves water by maintaining a high uniform application of irrigation and wetted diameter (Fandika et al., 2012). However low head drip irrigation resulted satisfactory result than high head system (Ngigi, 2008). To make the system economical and efficient, experiments should be done with various combinations of water supply head, lateral length, land slope, and bucket size to get an EU above 80%. Furthermore, to get more uniform discharge along the drip laterals, the diameters of the emitter micro-tube should be gradually increased with the increase of lateral length; further research is necessary to determine the appropriate diameters.

References

Ahmed, H. M. M., Salad, A. W. M., & Gomaa, Y. H. D. (2020). Hydraulic Performance of Three Types of Imported Emitters Used in Drip Irrigation Systems in Sudan, 12, 2:88–96.

de Oliveira, R. A., Ramos, M. M., & de Aquino, L. A. (2015). Irrigation management. In Sugarcane: Agricultural Production, Bioenergy and Ethanol, pp. 161–183.

Fandika, I. R., Kadyampakeni, D., & Zingore, S. (2012). Performance of bucket drip irrigation powered by treadle pump on tomato and maize/bean production in Malawi. Irrigation Science, 30,1: 57–68.

Hoque, M. (2017). The way ahead. In Biotechnology for Sustainable Agriculture: Emerging Approaches and Strategies, pp. 373–397.

IGBOJIONU, D. O., OBINECHE, C. I., & IGBOJIONU, J. N. (2021). Design, Development and Evaluation of a Bucket Drip Irrigation System for Dry Season Vegetable Production in South-Eastern Nigeria. Turkish Journal of Agricultural Engineering Research, 2,1:183–192.

Karlberg, L. (2003). Efficient irrigation and wastewater reuse in developing countries - an option that deserves further attention. Ecological Engineering, 20,1:11–21.

Kulecho, A.A. and Weatherhead, E.K. (2005). Low-cost drip irrigation for small-scale farmers in Kenya. Agricultural Water Management, 73,2:85–103.

Ngigi, S. N. (2008). Technical evaluation and development of low-head drip irrigation systems in Kenya. Irrigation and Drainage, 57,4:450–462.

Riza, A. N., Akhter, T., Akhter, F. & Khair, M. A. (2016). Evaluation and improvement of a low-head drip irrigation system to be used by small scale farmers in Bangladesh. Journal of Science, Technology and Environment Informatics, 04,1:251–259.

Teshome, Y., Biazin, B., Wolka, K., & Burka, A. (2018). Evaluating performance of traditional surface irrigation techniques in Cheleleka watershed in Central Rift Valley, Ethiopia. Applied Water Science, 8,8:1–14.

Zaher, M., & Mazid, M. A. (1992). Aquafeeds and Feeding Strategies in Bangladesh. In FAO/AADCP Regional Expert Consultation on Farm-Made Aquafeeds, 14–18 p.

Zhao, P., Ma, M., Hu, Y., Wu, W., & Xiao, J. (2022). Comparison of international standards for irrigation with reclaimed water. Agricultural Water Management, 274:107974.