Evaluation of low-head drip systems for vegetable farming in Bangladesh

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Abstract: Bangladesh is in the phase of introducing drip irrigation (DI) system in the country. Several types of drip emitters are now becoming available in the market although their performance indices are yet to be matched for local farming practices. This study reports the results of a series of experiments carried out to quantify the hydraulic performances indices of two different types of emitters available in Bangladeshi marketplace. One of the emitters, E1 was designed and manufactured locally, while the other, E2 was imported and highly priced. Followed by the hydraulic experiment, these emitters were also employed in comparative field experiments for tomato and brinjal production at Dumuria, Khulna, Bangladesh. Irrigation schedules were designed based on the local evapotranspiration regime. During the study, both the emitter types exhibited non pressure compensating features as their flow rate increased with pressure. Interestingly, both types of emitters gave a persistent trend of flow rate along the laterals. Standard uniformity indices for DI systems were also calculated, and the DI systems were categorized (good to excellent) based on the established guidelines for microirrigation. Very good performance indices were obtained at 3 m head for emitter E1, and at 2.5 m head for emitter E2. The results of the field experiments also showed that yield, water saving and water productivity of drip irrigated tomato was increased by 12%, 49.48% and 49% respectively when compared with furrow irrigation that is considered as a farmer practice. Similar results were also obtained for brinjal fields irrigated under DI systems. These experiments showed promising comparative benefits of drip technology for vegetable cultivation in water scarce coastal areas of Bangladesh.
Keywords: low-head emitter, drip irrigation, hydraulic performance, water productivity

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1 Introduction

Bangladesh is a victim of climate change induced sea level rise. As a result, the entire coastal belt of the country is facing an ever-increasing problem of soil (Hasheem, 2005) and irrigation salinity (Hossain and Siddique, 2015). Thirty two percent areas of the country are under coastal zone (Ahamed et al., 2020). Under the circumstances, judicious use of the available freshwater resources is of utmost importance, since agriculture thrives on it.

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Microirrigation offers a sustainable solution when it comes to using water efficiently in agriculture. In this regard, the Government of Bangladesh is in the early phase of introducing this technology to the country, particularly in the coastal area where winter vegetable production is affected by higher salinity (Uddin et al., 2009; Lam et al., 2022), lack of rainfall. The supply of freshwater during this time is therefore, very limited. This situation warrants radical technological intervention that could utilize the available surface water sources efficiently for food production. Drip irrigation system is therefore promoted as a promising water saving candidate (Hossain et al., 2014; Wang et al., 2021) for different crops along with vegetable farming in the coastal regions. This technology is known for its high water use efficiency (Khan et al., 2014) by maintaining soil moisture in the root zone close to field capacity (Sarker et al., 2019). It is also regarded for up to 30% to 70% of water savings in different orchard crops and vegetables together with 10% to 60% increases the production compared to traditional irrigation techniques (Challa et al., 2017).

In Bangladesh, gravity-fed surface irrigation methods are mostly popular amongst the vegetable farmers. Due to high initial investment and technical complexity, the adoption of microirrigation in vegetable farming is very slow amongst the farmers. In addition, due to lack of appropriate emitting devices and tools, the comparative benefit of drip technology could not be demonstrated to the farmers. In recent years, the technology is getting momentum as several types of emitters are being imported, and advertised in the market mainly by the private sector initiatives. Some of the emitters are also being manufactured in the country although their level of precision is understandably low and yet to be documented.

The exact manufacture of the emitter for drip irrigation method is crucial for its uniformity as emitters are the most important part of any drip irrigation system. Manufacturing coefficient of uniformity is therefore an important index in assessing how well the device is going to perform. The hydraulic performance data is also important since the information would provide for any variance that need to be adjusted for a particular drip system (Aydin, 2019; Sarker et al., 2019; Xing et al., 2021). Uniformity indices of a particular emitter are also supposed to be documented with the product. Unfortunately, the emitters available in Bangladesh have little or no information attached to them. The hydraulic datasheet is absent in most of the products. Without these information, effective operation of a drip irrigation system, and achieving higher water distribution efficiency in the field is practically impossible.

The common features of the emitters promoted in Bangladesh is that they are designed to work at low pressure head, usually less than three meters. The idea behind was to promote gravity fed pseudo-pressurized irrigation system for small scale farmers. The pressure is so designed that lifting a pot of water to a workable man-height above the ground would create sufficient head. The flow of emitter at such pressure is relatively low. During irrigation time, water level of the reservoir drops which decreases pressure of the water. For achieving a good circulated water network, the study of the behavior of such decreasing pressures as well as discharges through the main pipe and lateral pipe in the drip system is very important. This is because, the amount of pressure losses between the head of the lateral and that in the end of the laterals affects the discharge distribution of emitters and uniformity (Kang and Nishiyam, 1996). None of this information is available for emitters available in the Bangladeshi marketplace. This study reports the results of a series of experiments carried out to quantify the hydraulic performances indices of two different types of emitters introduced in the country. In addition, the performance of these products in tomato and brinjal production has also been reported for small scale drip irrigation system in the coastal area of Bangladesh.

2 Materials and methods

2.1 Emitters

This experiment was conducted at the research field of Farm Machinery and Postharvest Process Engineering Division of Bangladesh Agricultural Research Institute (BARI), Gazipur, during 2018-2019. Two different types of emitters (E1 and E2) were selected for performance evaluation. Emitter E1 was designed and manufactured in Bangladesh, and emitter E2 was imported from India into the local market. The pictorial view of emitter E1 and emitter E2s are shown in the Figure 1 and Figure 2, respectively. The specifications of both emitter E1 and emitter E2s are given in Table 1.

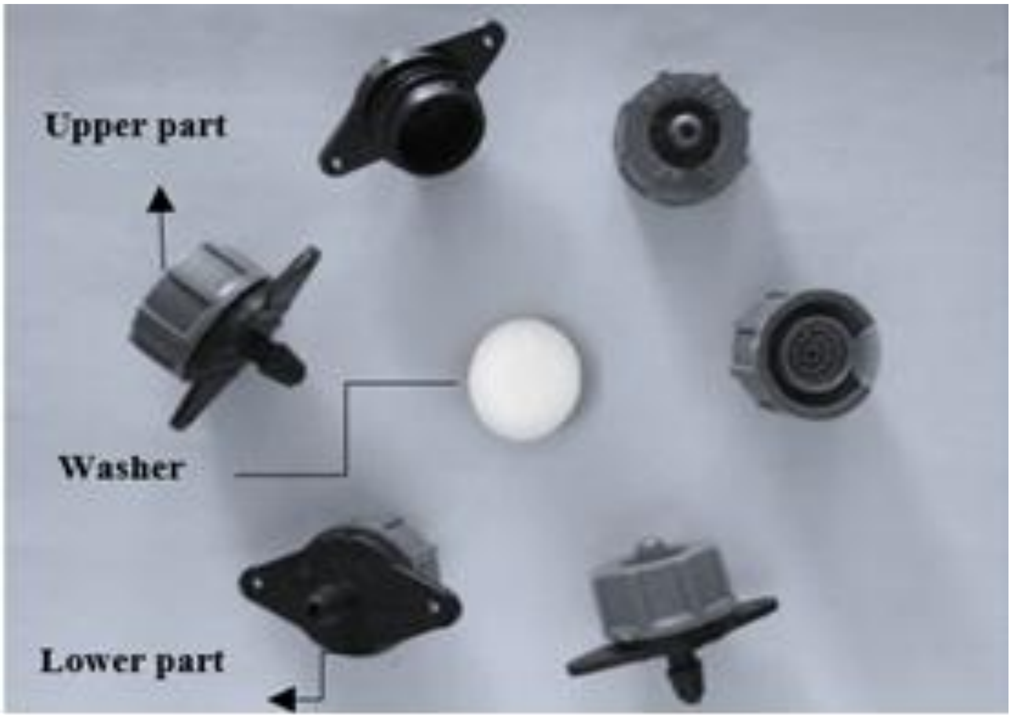


Figure 1 Different parts of emitter E1

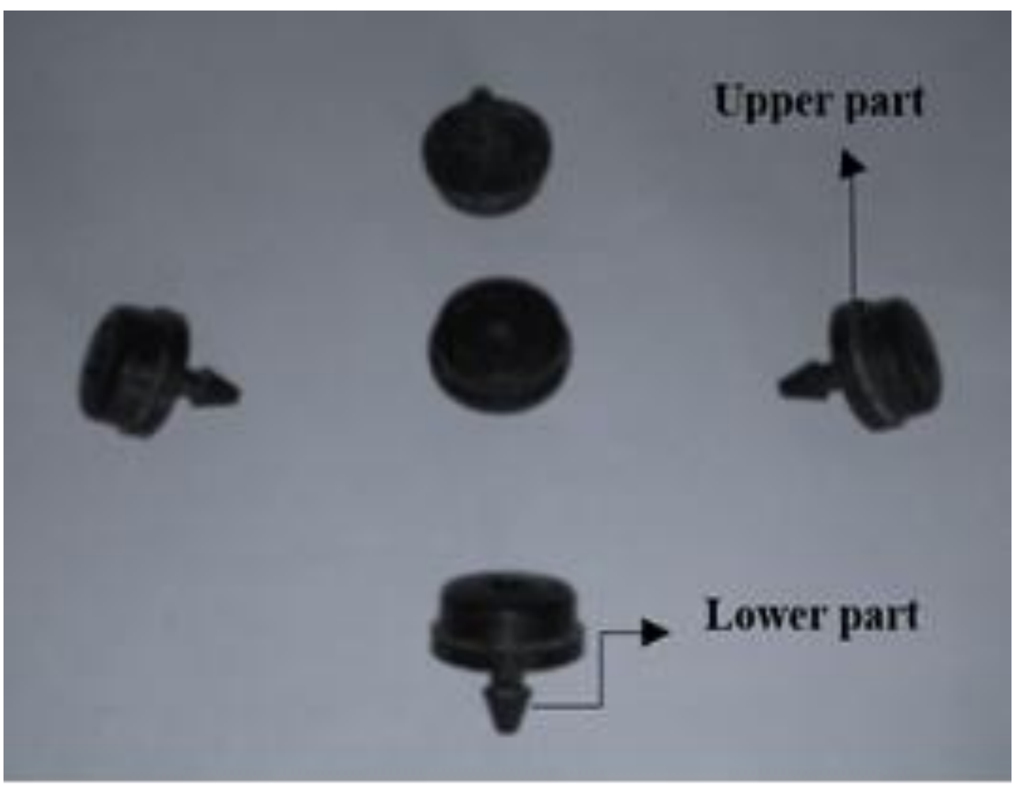


Figure 2 Different parts of emitter E2

Table 1 Specification of emitter E1 and emitter E2

Specification	Emitter E1	Emitter E2
Manufacturing country	Bangladesh	India
Flow rate, L h^{-1}	2.9-4.5	3.17-4.5
Shape of the emitter	Circular	Circular
Diameter of emitter (mm)	20	15
Diaphragm	Yes	No
Price per piece (USD)	0.12	0.37

2.2 Construction of the DI system for in-field hydraulic testing

A drip irrigation system was constructed with one mainline (19 mm diameter plastic pipe) which was subsequently connected to 9 plots via sub-mains and laterals. In each plot, there were four laterals (13 mm diameter plastic pipe) connected to the mains. Each lateral line was 4.5 m long having 6 number of emitters. There was a total of 216 emitters in 9 plots, and each plot were at different distance such as 8.3m, 13.3m, 18.3m, 23.3m and 28.3m from the water tank. The unit plot size of tested field was (4.5 m× 4 m). The layout of the DI system is shown in Figure 3.

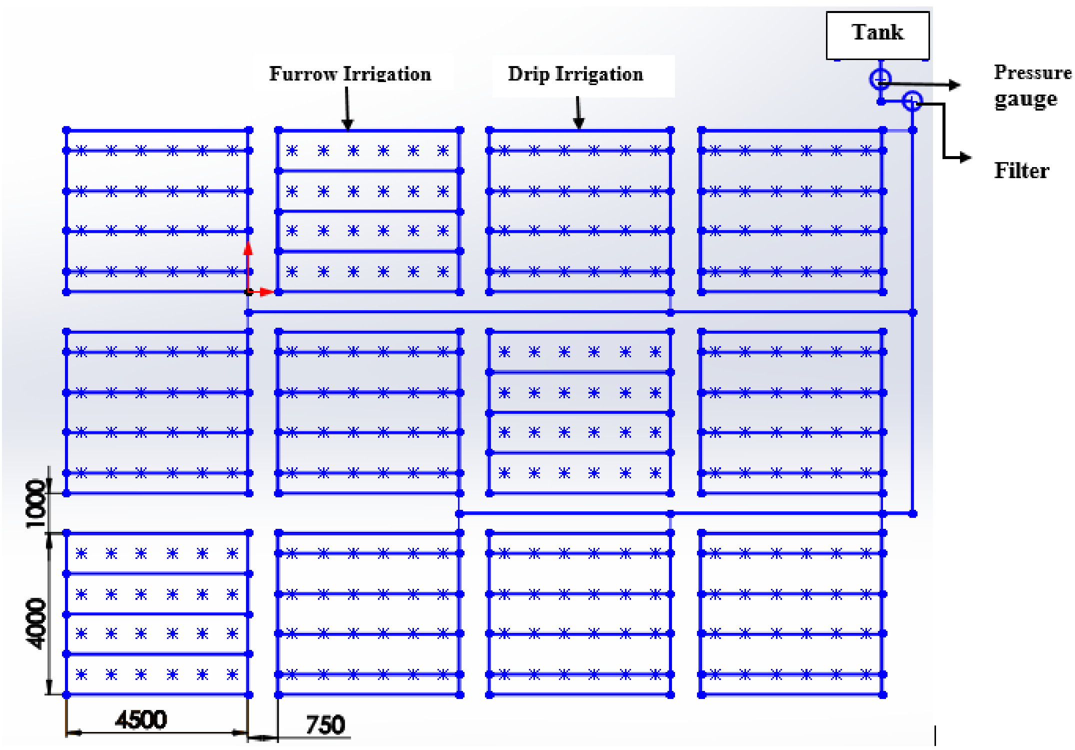


Figure 3 Layout of the test DI system in the experimental field (all dimension in mm)

A 500 L water tank was the main water source for the system and was placed on top of a metal stand. A constant water head was maintained by supplying water from an external water supply system. A screen filter (Model-122Y) was used for filtering the water before delivering to the system. The system pressure was measured by a pressure gauge. Laterals were spaced 1.0 m apart from each other. Emitters were fitted in the lateral pipe at a distance of 0.75 m from each other. Emitters were tested to different heads such as 1.5 m, 2.0 m, 2.5 m and 3.0 m. In a typical test run, for a particular pressure, 40 emitters were used for discharge measurement under a particular head (ASABE *Standards*, 2006; Bloomer, 2010). The water flowed through each emitter was collected in beaker and then measured by a measuring cylinder.

2.3 Measurement of discharge rate

At first the gate valve was opened and water was allowed to flow the drip system from the water tank and conditioning was done according to the protocol of ASABE *Standards* (2006). Followed by the conditioning, a particular pressure head was set and maintained to collect the discharges. In order to collect the flow from an emitter, beakers (300 mL) were placed under the laterals for a period of at least 3 minutes. The collected water was then measured using digital balance to obtain the hourly flowrate of an emitter. A stop watch was used to measure time accurately. Using this protocol, pressure heads were precisely varied from 1.5 to 3.0 m The average flow rate ($\overline{q_l}$) in a lateral for emitter E1 and emitter E2 was calculated by averaging the flow of five random emitters (n = 5) along each line.

$$\overline{q_l} = \frac{1}{n}\sum_{i=1}^{n} q_l \quad (1)$$

where, q_i is average discharge (L h^{-1}) of the i^{th} emitter and n is total number of emitters.

2.4 Hydraulic performance indices

2.4.1 Manufacturing coefficient of variation

This is measure of the variability of discharge of a random selected sample of a given model and size of emitter. The value of C_v (Coefficient of variation) can be estimated from measured discharge of a sample set of emitters operated at a reference pressure head (Tiwari and Raghuwanshi, 2014). The classification of emitters based on C_v was recommended by ASABE *Standards* (2008) and is widely used in the microirrigation industry.

$$C_v = \frac{S_d}{\overline{q}} \quad (2)$$

where, C_v is manufacturing coefficient of variation of emitter flow, S_d is standard deviation of emitter flowrates at reference pressure head (L h^{-1}), $\overline{q}$ is mean emitters flowrate in the sample at that reference pressure head (L h^{-1}).

2.4.2 Christiansen's coefficient of uniformity

It is generally calculated the absolute deviation of the discharge data of emitter from the average value. CU_c is calculated using the Christiansen formula (ASABE *Standards*, 2003)

$$CUc = 100\left[1 - \frac{\sum_{i=1}^{n}\left|q_i - \overline{q}\right|}{n\overline{q}}\right] \quad (3)$$

2.4.3 Distribution uniformity

It indicates how equally water can be distributed during irrigation in the field through a drip system. The recommended acceptability range of emitters based on *DU* was recommended by Burt (2004). *DU* of irrigation systems can be calculated by following formula (Marriam and Keller, 1978)

$$DU = 100 \times \frac{\overline{q_{\frac{1}{4}}}}{\overline{q}} \quad (4)$$

where, $q_{\frac{1}{4}}$ is average of lowest 1/4th of measured emitter flowrate (L h^{-1}) .

2.4.4 Statistical uniformity of water application

Statistical uniformity of water application mainly used to define emitters emission uniformity in the laterals lines of the irrigation system only. Statistical uniformity of water application was computed using following equation (Pranav et al., 2017).

$$US = 100(1.0 - \frac{S_d}{\overline{q}}) = 100(-C_v) \quad (5)$$

2.4.5 Design emission uniformity

Emission uniformity is one of the important features of hydraulic parameter of emitter which is frequently used to assess the predicated flow variation of emitter along the lateral line (Sarker et al., 2019).

$$EU = 100[1.0 - \frac{1.27CV_m}{\sqrt{n}}]\frac{q_{min}}{\overline{q}} \quad (6)$$

where, q_{min} is minimum emitter flow rate (L h^{-1}) and CV_m is manufacturer's coefficient of variation of emitter.

2.5 Weather condition in experimental site

The daily meteoroidal data were collected from nearby weather station in Khulna. Geographical data includes latitude, longitude and elevation of the selected place and climatic data includes daily maximum and minimum temperature (^{o}C), relative humidity (%), sunshine hour (hours) and wind speed (km day^{-1}) at 2 m height. Reference crop evapotranspiration, effective rainfall and radiation were calculated by Penman-

Monteith's equation using FAO developed CROWAT computer Software 8.0 (Kuslu et al., 2010) on a daily basis from daily meteorological and geographical data.

2.6 Field experimental design

A field experiment was designed involving emitter E1for tomato and brinjal cultivation in Dumuria, a coastal area of Bangladesh during the winter season of 2019-2020 (Figure 4). The coordinates of the experimental area in Khulna are 22°48′0´N and 89°33′0´E, which is located at the elevation of 9 m above sea level. The type of the soil was sandy loam with average field capacity of 30.62% and bulk density of 1.5 g cm^{-3} in Table 2.

Table 2 Analytical data of soil sample at farmers field in Dumuria, Khulna

	Parameter	Soil depth, cm			
		0-15	15-30	30-45	45-60
Physical Properties	Field capacity (%)	32.57	31.36	30.13	28.42
	Bulk density (g cm^{-3})	1.44	1.48	1.51	1.56
	Sand (%)	48.00	52.00	56.00	60.00
	Silt (%)	33.28	27.28	29.28	25.28
	Clay (%)	28.72	20.72	14.72	14.72
Chemical Properties	pH	8.0	8.6	8.6	8.5
	OC%	0.70	0.31	0.22	0.25
	Ca (meq 100 g^{-1})	11.8	11.7	11.2	11.7
	Mg (meq 100 g^{-1})	3.9	3.8	4.0	3.8
	K (meq 100 g^{-1})	0.27	0.21	0.18	0.11
	Total N%	0.064	0.028	0.02	0.023
	P, µg ml^{-1}	59	12	12	25
	S, µg ml^{-1}	70.4	49.2	53.5	68.9
	B, µg ml^{-1}	0.60	0.10	0.42	0.10
	Zn, µg ml^{-1}	2.80	1.78	1.12	0.73

Figure 4 Pictorial views of tomato and brinjal field in Dumuria, Khulna

The field experiment for both tomato and brinjal was laid out in randomized complete block design (RCBD) with two treatments that were replicated thrice. Treatment T_1 involved drip irrigation method based on three (tomato) days and five (brinjal) days of median cumulative evapotranspiration data. The crop growing period of tomato and brinjal plants was 120 days and 150 days respectively. The drip technology was compared with another treatment, T_2 which employed furrow irrigation system (farmers' practice). The unit plot size for tomato field was 4.8m ×3.6 m and that for brinjal field was 4.5 m× 4 m. The rate of fertilizer applications of tomato per ha of the land were N_{136}, P_{40}, K_{113}, Zn $_{2.98}$, $B_{1.41}$ and S_{15} kg and it was N_{138}, P_{50}, K_{100}, $Zn_{3.42}$, $B_{1.62}$ and S_{18} kg for brinjal as recommended by FRG (2018) for Bangladeshi soil types. The muriate of potash and urea fertilizers were applied in three equal installments as side dressing in the row of brinjal plant by 15, 30 ,60 days after transplanting and tomato plants by 10, 25 and 40 days after transplanting. Organic manures and fertilizers were applied well as top-dressing. The cow dung of one third and full of TSP and gypsum were applied during final land preparation. Rest of cow- dung was applied as basal in pit. Zinc oxide and boric acid were applied in each plot one week after transplanting. The weeding and pesticide spraying were done when necessary. The seedlings of 30 days plants of tomato (Roma VF) and brinjal (local variety) were transplanted on 30 November 2019, and were harvested on 1 April 2020 and 26 April 2020, respectively. Standard agronomic procedure was maintained throughout the cultivation period.

2.7 Irrigation scheduling

Irrigation scheduling was carried out using CROPWAT computer software 8.0 (Kuslu et al., 2010). Based on the daily meteoroidal data, irrigation requirement was computed by subtracting effective rainfall from the measured crop evapotranspiration (Bennett et al., 2014). The seasonal water use was estimated for each treatment by the following equation (Michael, 2008).

$$ACWU = IR + Rf + \sum_{n=i}^{n} \frac{(M_{bi} - M_{ei})A_{Si}D_i}{100} \times Asi \times Di \quad (7)$$

where, *SCWU* is seasonal consumptive water use (mm), *IR* is the amount of irrigation water applied during the crop season (mm), R_f is seasonal effective rainfall (mm). Mb_i is percentage of moisture content at the beginning of the season of i^{th} layer of the soil, Me_i is percent moisture content at the end of the season of i^{th} layer of the soil and n is number of the soil layer considered, D_i is depth of i^{th} layer of the soil within the root zone (mm), As_i is the apparent specific gravity of i^{th} of the layer of the soil. In order for this, soil samples were collected from both tomato and brinjal fields in 15 cm increments up to 60 cm depth at the time of sowing, before irrigation, after rain fall and also at the harvesting time.

The water use of crop field is generally described in terms of water productivity (*WP*). It is the ratio of crop yield to the total amount of the water used in the field during the entire growing period of the crop. The water productivity for tomato and brinjal were calculated by using the following equation (Sarkar et al., 2016).

$$WP = \frac{Y \times 100}{SCWU} \quad (8)$$

where, *WP* is water productivity (kg m^{-3}), and *Y* is grain yield (kg m^{-2}).

The percentage of water saving in drip irrigation compared to furrow irrigation method was calculated using the following equation (Chapagain and Yamaji, 2010).

$$Water\ saving = \frac{Irrigation\ water\ applied\ in\ furrow\text{-}Irrigation\ water\ applied\ in\ drip}{Irrigation\ water\ applied\ in\ furrow} \times 100 \quad (9)$$

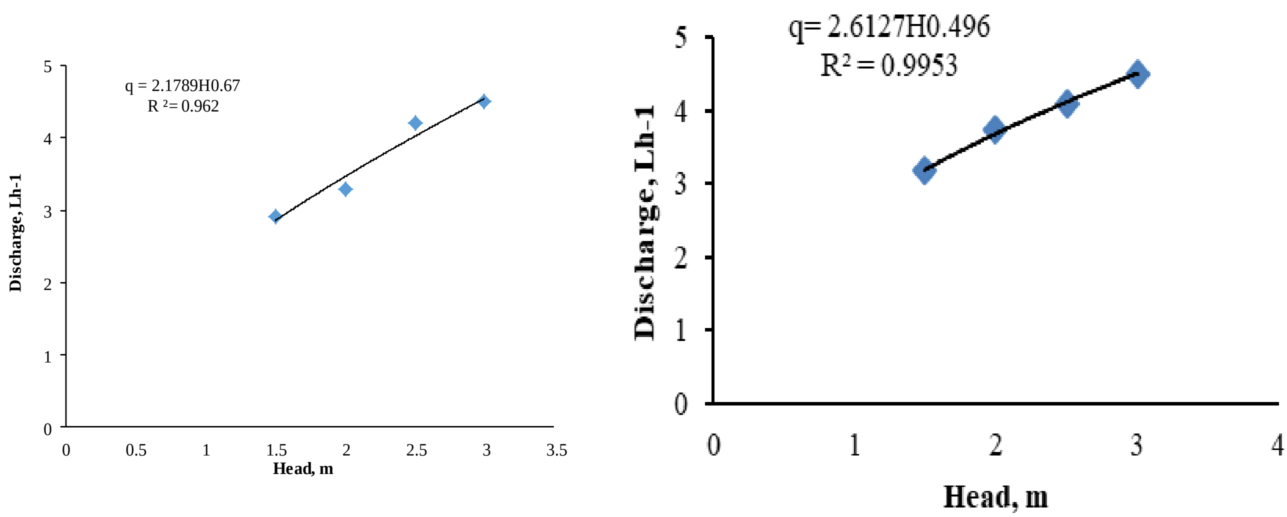
2.8 Water quality

In Dumuria, Khulna there are different water bodies that are used for irrigation purpose, fishing as well as other livelihood activities. The source of water for drip and furrow irrigation purpose was pond water. The pond water sample was collected for measuring salinity, pH and total dissolved solid in rabi season (December-April) at every 10 days interval during 2019-2020. The water salinity of pond was measured for observing irrigation water quality. A portable instrument of soil and water conductivity meter (Model no-EZ-9908) having sensor probe that directly put into different water sample and indicates water salinity, pH and TDS reading of the water samples.

3 Results and discussion

3.1 Head-discharge relationship

The head and flow rate relationship plays a crucial role for right selection of emitter of any drip irrigation system. In this experiment, 1.5 m, 2.0 m, 2.5 m and 3.0 m of pressure heads were employed and the corresponding flow data were obtained at 0% slope. The relationship between head and discharge in different pressure head has been shown in Figure 5. The results suggests that the emitters were very responsive to pressure changes and hence, were non-pressure compensating (n-PC).



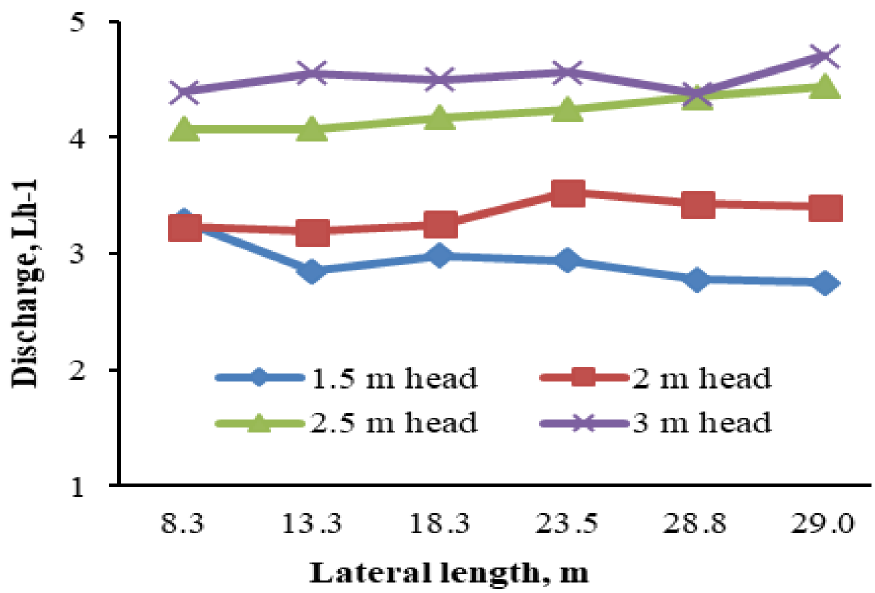
(a) Emitter E1 (b) Emitter E2

Figure 5 Head and discharge relationship of emitter E1 and emitter E2

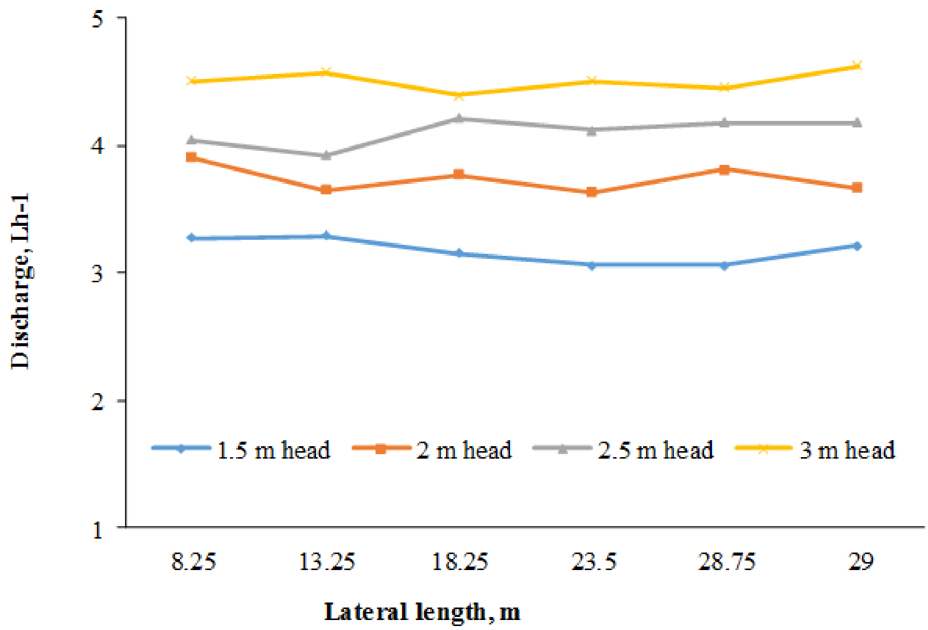
The n-PC characteristics of the emitters were also evident from the polynomial regression equation ($q = k \times h^x$) governs the flow (q, L h^{-1}) through point source emitters (Dutta, 2008) at a particular head (h, m). Accordingly, the value of emitter exponent x was found to be 0.67 for emitter E1 and 0.50 for emitter E2 which also confirms that both types of emitters have n-PC characteristics. This is because, x > 0.5 indicates non-pressure compensating features (Dutta, 2008).

3.2 Flow along the laterals

The flow pattern along the laterals for emitter E1 and emitter E2 at different pressure heads has been presented in Figure 6. In case of emitter E1, flow variation along the lateral was limited to 6%, 11%, 9% for 3 m, 2.5 m and 2.0 m pressure head, respectively. In case of 1.5 m head however, higher flow variation (15%) was recorded. On the other hand, laterals of emitter E2 performed better since flow variation along the lengths was found to be less than 7% at all the operating heads.



(a) emitter E1



(b) emitter E2

Figure 6 Flow along the lateral lengths at different heads for emitter E1and emitter E2

3.3 Uniformity indices

Uniformity indices were also calculated for both the emitters as shown in Table 3. The coefficient of flow variation for emitter E2 was found between 4%-6%, which according to ASABE *Standards* (2008) falls in the 'average' to 'excellent' category of system. The other emitter E1 however, could not perform well as its C_V ranged between 10-12% falling between 'marginal' to 'poor' category of DI system. With regards to the statistical uniformity (US) which is a function C_V, emitter E2 falls into the 'excellent' category while E1 falls into the 'very good' category according to ASABE *Standards* (2008).

The most important index for microirrigation is the distribution uniformity of the lower quarter. It measures how well an irrigation water is delivered to the plants receiving the least amount of water. Capra and Scicolone (1998) implied that a higher DU value (up to 96%) could be gained through drip irrigation system. Usually for high-value crops, higher values of DU are recommended, and in case of deep-rooted crops less values might be acceptable (Maroufpoor et al., 2010; Fandika et al., 2012). In this experiment, the DU values for emitter E2 ranged above 90% at all operating heads (Table 2). This means DI system with emitter E2 could be excellent in delivering water to the plants according to ASABE *Standards* (2008). On the other hand, emitter E1 appears to have performed well (DU=90%) at 3 m pressure head. In other cases, DU was still in the 'very good' category with DU ranging between 85% and 87%.

Table 3 Uniformity indices of emitter E1 and E2 at different operating heads

Parameter	Emitter E1				Emitter E2			
Operating Head, m	1.5	2.0	2.5	3.0	1.5	2.0	2.5	3.0
C_v	0.12	0.11	0.12	0.10	0.06	0.05	0.04	0.05
CU,%	89	90	87	91	99	99	99	99
DU,%	85	87	86	90	93	95	96	93
US,%	89	90	88	90	94	95	97	95
EU,%	81	84	87	87	87	90	88	88

For high-value crops, the recommended value of CU is higher than 75% (Fandika et al., 2012). In this study CU value for emitter E1 was found 87%-91% and CU for emitter E2 was found 99%. The EU values of emitters for 1.5-3.0 m pressure head showed that EU was found more than 80% for emitter E1 and more than 90% for emitter

E2. According to Merriam and Keller (1978) the values of EU showed good to very good result for both type of emitters and worked effectively even under low operating head. Based on the hydraulic performances, emitter E2 was found to be slightly superior to emitter E1. However, the cost of E2 was high compared to emitter E1. Considering the advantages of the marginal farmer, the field experiment was therefore, carried out using emitter E1 which was locally made. The device is also readily available in the country and our research recommends this specimen for microirrigation practice in the coastal part of Bangladesh.

3.4 Weather data

The different weather parameters during crop growing period (December-April) of 2019-2020 in the study area is shown Table 4. Using this information, the reference crop evapotranspiration (ET0) was calculated for each month of the study period. This evapotranspiration data was used to calculate the irrigation demand of the crop for a cumulative 3 days' interval. The total rainfall was recorded to be 226 mm during the experimental period.

Table 4 Weather data during the crop growing period of 2019-2020 in Khulna

Month	T_{max}	T_{min}	RH (%)	Wind Speed (km/h)	Sunshine Hour	Rainfall (mm)	ET0
December,2019	29.5	11.6	80	50	4.4	15	1.85
January,2020	29.2	11.2	79	60	5.4	30	2.12
February, 2020	30.5	10.8	66	68	6.7	2	2.91
March, 2020	36.0	16.6	58	90	8.3	0	4.30
April, 2020	37.0	21.4	67	117	7.3	179	4.88

3.5 Growth and yield attributes of tomato and brinjal

The growth parameters of plant height and number of branches per plant in tomato and brinjal are given in Table 5. According to the results it was implied that both tomato and brinjal maximum plant height and no of the branches per plant were found in drip irrigation system than those of the furrow irrigation practice. At first harvest the height of the tomato plant varied significantly from drip irrigation system (73.22 cm) than furrow (70.43 cm) but at last harvest there was no significant different observed. On the other hand, in brinjal at first harvest there was no significant difference observed but at last harvest the height of the tomato plant varied significantly from drip irrigation system (116.36 cm) than furrow (96.31 cm). In case of number of the branches per plant, at first harvest there was no significant difference noticed in both tomato and brinjal plant but in case of brinjal at last harvest, the number of the branches per plant varied pointedly in drip irrigation system (23.22) than furrow (20.00).

Table 5 Growth contributing parameters of tomato and brinjal in different treatments during 2019-20

Crop	Treatments	Plant height (cm)		No of branch/plant	
		At first harvest	At last harvest	At first harvest	At last harvest
Tomato	T_1 (*Drip*)	73.22 ^{a}	94.12 ^{a}	14.20 ^{a}	19.49 a
	T_2 (*Furrow*)	70.43 ^{b}	90.76 ^{a}	11.67 ^{b}	14.18 a
Brinjal	T_1 (*Drip*)	48.66 ^{a}	116.36 ^{a}	9.62 ^{a}	23.22 a
	T_2 (*Furrow*)	42.58 ^{a}	96.31 ^{b}	8.71 ^{a}	20.00 b

In order to quantify the comparative benefit of drip irrigation with locally made emitter in terms of yield and water saving, field experiments were carried out with tomato and brinjal. Yield and yield contributing characters of the crops during the experiment under two types of irrigation systems (DI system with E1, and furrow irrigation) are given in Table 6. According to the results, tomato and brinjal yields were significantly higher (12% for tomato and 13% for brinjal) in treatment T_1 (Drip irrigation) compared to treatment T_2 (Furrow irrigation). There were no significant differences in the number of fruits per plants, but fruits obtained from treatment T1 were significantly healthier. This can be seen in Table 3 where the fruit length and diameter along with the unit weight of fruit for both tomato and brinjal plants were higher for drip irrigated plots. Improvements in the yield of crops under drip irrigation have been documented in the literature. For instance, Hartz and Hanson (2009) showed that drip irrigation system causes better nutrient consumption in tomato resulting in higher yield and better-quality products. Similar results have also been reported by Sarker et al. (2019) and Palada et al. (2011) reported nearly 19% and 15% increase in the yield of tomato and brinjal, respectively for different regions of South Asia.

Table 6 Yield and yield contributing parameters of tomato and brinjal in different treatments during 2019-20

Crop	Treatments	Number of fruit/ plant	Fruit Length (cm)	Fruit Diameter (cm)	Unit weight of fruit (g)	Yield (t ha^{-1})
Tomato	T_1 (*Drip*)	52.73 ^{a}	5.72 ^{a}	4.41 ^{a}	60.55 ^{a}	55.51 ^{a}
	T_2 (*Furrow*)	48.00 ^{a}	5.18 ^{b}	4.07 ^{b}	54.36 ^{a}	49.03 ^{b}
Brinjal	T_1 (*Drip*)	32.49 ^{a}	12.96 ^{a}	7.23 ^{a}	171.14 ^{a}	27.91 ^{a}
	T_2 (*Furrow*)	28.60 ^{a}	11.67 ^{b}	6.17 ^{b}	165.60 ^{a}	24.30 ^{b}

3.5 Water saving and water productivity of tomato and brinjal

Amount of water applied, water productivity and water saving in drip irrigation over furrow irrigation of tomato and brinjal cultivation are given in Table 7. During the crop growing period (December, 2019- April, 2020), the highest amount of water applied for tomato (440 mm) and brinjal (535 mm) was in furrow irrigation method. In comparison, drip irrigation method consumed 226 mm water for tomato and 363 mm for brinjal. This means water saving through drip irrigation method were 49% and 32%, respectively when compared with furrow irrigation. Different studied showed similar result (Sarkar et al., 2018; Hossain et al. 2014). Water productivity is intensely related to the variation of climatic condition. Water productivity becomes lower with the increasing amount of water supply and vice versa. Water productivity of tomato and in drip irrigation was increased of 49.48% and 38.79% respectively compared to furrow irrigation method. These results showed similarity with Thamer et al. (2021). The results implied that drip irrigation using locally designed and manufactured emitters could be a sustainable method for irrigation compared to the existing farmers' practice (flooding or furrow irrigation). Since significant water saving is possible as demonstrated by this research, the technology was recommended for water scarce of Bangladesh.

Table 7 Water productivity and water saving in in different treatments of tomato and brinjal field during 2019-2020

Crop	Treatments	Irrigation water applied (mm)	Soil water contribution (mm)	seasonal water use (mm)	Water productivity (Kg m^{-3})	Water saving (%)
Tomato	T1 (*Drip*)	226	16	288	19.3	48.64
	T2 (*Furrow*)	440	17	503	9.75	-
Brinjal	T1 (*Drip*)	363	29	423	6.60	32.15
	T2 (*Furrow*)	535	30	594	4.04	-

3.6 Water quality

Water salinity, pH and total dissoved solid in the irrigation water during the crop growing season of 2019-2020 is given in Figure 7. The water salinity of pond ranged betwen 1.18-2.55 dS m^{-1} from the staring of cropping period (December) to the end of the season (April). This indicated slight to moderate salinity and safe for irrigation purpose FAO (1976). The ranges of the pH and TDS of pond water was 6.65-7.01 and 558-1278 ppm, respectively. According to the published (FAO, 1976; Mahtab and Zahid, 2018) water quality guideline, the pH of pond water was found to be safe for irrigation.

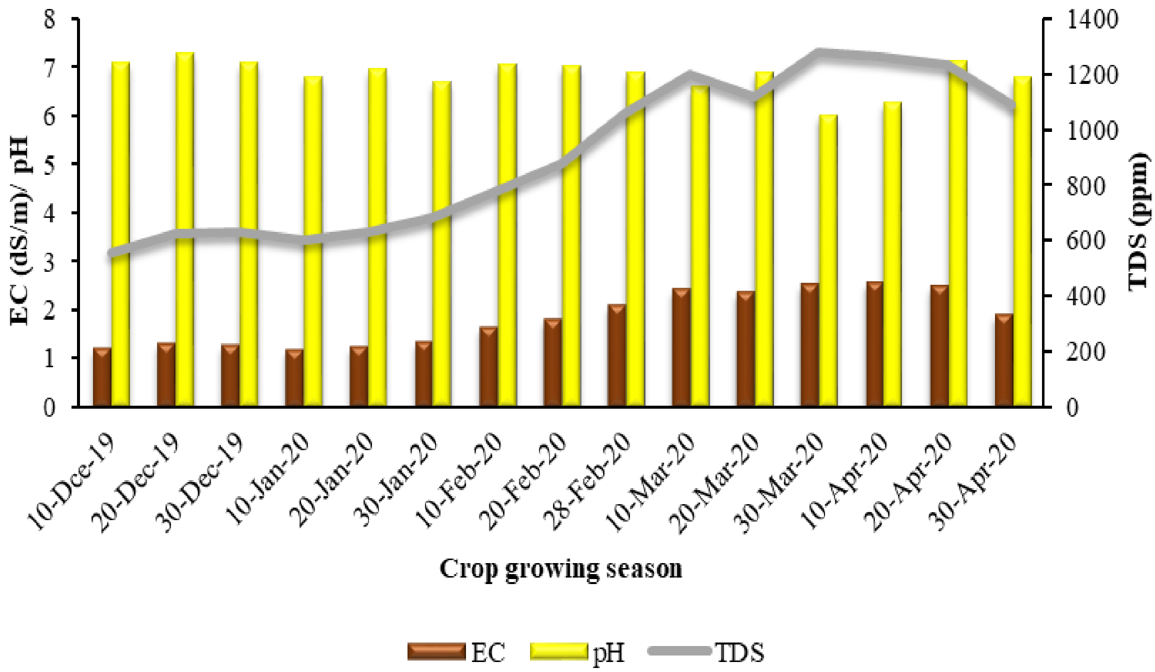


Figure 7 Water quality indices for pond water during 2019-2020

4 Conclusions

This experiment evaluated the hydraulic and field performances of two different types of emitters available in Bangladesh which is at the early stage of introducing drip technology. Emitter E1 was designed and fabricated locally while E2 was imported into the country. The hydraulic experiment revealed that both the emitters were of non-pressure compensating type. Both emitters showed good result in terms of uniformity although flow variation was higher in emitter E1. Average discharge rate of both types of emitters was found to be more than the recommended values provided by the manufacturer. In case of emitter E2, it was difficult to clean and maintain due to its compact assembly which was not possible to open. On the other hand, emitter E1 had grooved assembly which would easily open. The price of emitter E2 was three times more than emitter E1 which will increase the production cost. The slightly superior performance of E2 was therefore outweighed due to the cheaper price of the local emitter. In a field investigation with tomato and brinjal, emitter E1 was employed in a drip system along with furrow irrigation method. The objective was to quantify the comparative benefit of DI technology in terms of yield, water productivity, and water saving of tomato and brinjal. The results indicated that drip technology uses 32%-50% less water than furrow method while producing higher yield in tomato and brinjal. Considering all these factors locally made emitters were recommended for vegetable farming in the water scarce areas of Bangladesh.

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