Evaluation of Pressure Compensating Drip Emitters fitted in a Polyvinyl Chloride Pipe

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ABSTRACT

Evaluating the effect of pressure head on the water distribution uniformity in a polyvinyl chloride (PVC) drip irrigation system is important in irrigation water management and could serve as the basis for optimizing water use efficiency and improving crop productivity. This laboratory study was to evaluate pressure compensating (PC) drip emitters fitted in a PVC pipe. A 6.00 m length PVC pipe with five selected randomized emitter points on each lateral were considered for five (5) different operating pressure heads (OPH) (1.60, 1.40, 1.20, 1.00, and 0.80 m) at 10, 20, and 30 minutes dripping interval and was repeated three (3) times each. PC drip emitters used in this study had a design or manufacturing discharge rate of 10 L/h and a 3/4 mm emitter diameter at an emitter interval of 0.35 m for corn planting specification. Uniformity Coefficient (UC) values for all OPHs were above 90% and classified as excellent based on criteria for assessing drip irrigation system. Emission Uniformity (EU) values decreased as OPH was reduced. Low EU values showed that OPHs of 1.00 m and 0.80 m were highly unrecommendable for the adoption of PVC drip irrigation systems. Larger values for average emitter discharge (Qvar) were obtained as OPH was reduced. Larger Qvar values proves unacceptable drip emitter characteristics. Flow variations is essentially kept minimum as the OPH is increased. Except for the 1.60 m OPH, the coefficient of variation (CV) for all OPHs was unsatisfactory. As a result, the 1.60 m OPH is recommended over the other OPHs considering the lateral length in the study.

Keywords: Pressure compensating, Drip emitters, Operating pressure head, PVC, Distribution uniformity

1.0. INTRODUCTION

Due to the continual rise in population, rising demand for food, and increased pressure on land accessible for agriculture, as well as the overwhelming influence of climate change, there is an urgent need to boost water productivity and water application efficiency. Water as a finite resource must be dispensed and managed effectively through the use of well-managed water-saving irrigation systems (Raphael et al., 2018). Irrigation technology has evolved in tandem with advances in water technology, water transport, and agricultural systems. The efficient and sustainable use of water for agriculture has become a global issue, and it contributes to the advancement of agricultural production processes (Jusoh et al., 2020). Over-irrigation wastes water and energy and can result in nutrient leakage from the root zone, surface soil erosion, and a decrease in soil air content. Drip irrigation has rapidly grown around the world as a result of water shortage and scarcity worries in many places of the world and is projected as a revolutionary irrigation technology for keeping the soil root zone wet (Soomro et al., 2013; Tayel et al., 2019). Compared to other irrigation methods, the drip irrigation method provides high uniformity, typically using about 30 to 50% less water than the other irrigation systems as they provide only the water needed by plants. When correctly designed, implemented, and managed, it is an effective kind of irrigation that may have water application and crop water consumption efficiency as high as 90-95%, as the system design necessitates meticulous engineering. Irrigation schedule may be carefully regulated to match crop demands, promising better yield and quality. The crop root structure and soil characteristics influence the choice of emitter spacing and tape depth (Shock, 2013). The water is made to flow under the effect of gravity, and the water pressure in the system is proportional to the ground level. A pressurized pipeline with an inline or online emitter is used in a lateral drip irrigation system. These pipes are often composed of polyvinyl chloride (PVC) or polyethylene hose, which does not disintegrate rapidly when exposed to direct sun light. As water flows through the laterals, pressure head loss occurs, resulting in a pressure differential between the head and tail ends. This water goes along a predetermined path inside the emitter, and some head is lost in the process. There are also some local losses produced by the emitter barbs protruding into the flow. Pressure compensating (PC) emitter characteristics under low pressure are significant for the design of gravity-fed drip irrigation systems (Asenso et al., 2014).

Emitters are defined hydraulically by their necessary operating pressure heads (OPHs) and nominal flow, and information on the flow of emitters and their flow regime is critical for the design and maintenance of a drip irrigation system. According to basic hydraulic principles, drip emitter discharge is an exponential function of emitter head. The actual head at the emitters will vary throughout the system due to friction and slight losses along the pipeline as water is carried from the source to the emitters. Water distribution uniformity is a significant aspect in assessing the efficiency of drip irrigation system design. The efficiency of the drip irrigation system is determined by the uniformity of water distribution, which may be evaluated by monitoring the flow rate in each emitter. Drip irrigation system performance is also affected by emission uniformity (EU) throughout the system, which assesses the consistency of emissions emitted by all emitters. The co-efficient of variation (CV) and the uniformity co-efficient (UC) are two more metrics that are also taken into account (Herman, 2014).

When building an effective drip irrigation system, the mix of OPH, lateral length, and land slope must be addressed to produce a superior water distribution uniformity. The OPH is particularly significant in the design of drip irrigation systems. Failure to deliver adequate OPH will result in decreased performance, which will contribute to system failure. No systematic study has been conducted to identify recommended OPH for such low-cost drip systems to achieve specific degrees of water distribution uniformity. The purpose of this study was to assess the effect of OPH (1.60, 1.40, 1.20, 1.00, and 0.80 m) and dripping interval of 10, 20, and 30 minutes on the water distribution uniformity of a PC drip emitters fitted in a PVC pipe.

2.0. MATERIALS AND METHODS

2.1. Description of study area

The research was carried out at the Agricultural Engineering Department Workshop at the School of Agriculture, University of Ghana, Legon, between 19th April and 7th of May 2021, in latitude 5° 39' 1.79" N and longitude 0° 11' 7.80" E.

2.2. Materials and Specifications

The materials used in the study were essential to ensure precision and reliability. The materials included a ½ inch (0.0127 m) PVC pipe, 6.00 m in length, with ½ inch (0.0127 m) end caps, elbows, taps, and connectors for constructing the irrigation system. A 2 mm drill bit and drill machine were utilized for precision drilling. The drip emitters used were ¾ mm pressure compensating emitters with a discharge rate of 10 L/h. Water storage was facilitated by a 50-liter tank, mounted on a 1.60 m wooden stand to serve as the pressure head. Measurement tools included a measuring tape, a cutter, and a 1000 ml beaker to measure emitter discharges at randomized points along each lateral. Markers were used for identification purposes. Collection cans, specifically 500 ml disposable cups, were used to collect drippings from the emitters, which were then transferred to the beaker for final discharge readings from five randomized sampled drip emitters on both laterals. Additional materials comprised paper sellotape, Teflon tape for secure connections, lateral supports to maintain the position of the lateral lines to ensure proper flow into the collection cans, plastic glue, and a stopwatch to monitor emitter dripping times at intervals of 10, 20, and 30 minutes. These materials facilitated a controlled and precise experimental setup necessary for the evaluation of pressure-compensating drip emitters in PVC pipes.

2.2. Experimental Setup

A controlled laboratory experiment was conducted to evaluate the performance of pressure-compensating drip emitters installed in polyvinyl chloride (PVC) pipes. This experiment utilized a 50 L container as the water supply, connected to half-inch PVC lateral pipes, each 6 meters in length. To simulate different pressure conditions, the water supply was mounted on a wooden stand with adjustable heights of 1.60 m, 1.40 m, 1.20 m, 1.00 m, and 0.80 m. The pressure heads were varied by adjusting the height of the wooden stand, ensuring a range of pressures could be tested. The lateral pipes were aligned as closely as possible to the ground contour to minimize pressure fluctuations caused by elevation changes. Each lateral contained seventeen emitters, spaced 0.35 m apart, suitable for deep silt loam soils used in maize cultivation, with lateral lines separated by 0.65 m to match maize planting distances. Five emitter points were randomly selected from each lateral for detailed measurement. Water flow was initiated from the 50 L container through the lateral pipes, and the discharge from the selected emitters was collected at intervals of 10, 20, and 30 minutes using disposable plastic cups. Timing was controlled with a calibrated stopwatch, ensuring precise measurement intervals. The collected water volumes were measured with a calibrated beaker to ensure accuracy and consistency. Each time interval test was replicated three times to ensure the reliability and reproducibility of the results. The uniformity of the emitter discharge was assessed using the catch-can method, as recommended by the American Society of Agricultural and Biological Engineers (ASABE, 1999). This method involved placing catch cans beneath the emitters to collect the discharged water, allowing for precise measurement and analysis of the water distribution uniformity. The collected samples were then analyzed to determine the performance of the pressure-compensating emitters under varying pressure conditions simulated in the experiment.

2.3. Evaluation Procedure

The evaluation was carried out in accordance with the American Society of Agricultural and Biological Engineers' standards (ASABE). These approaches are based on measuring the discharge of emitters along the laterals. On each 6.00 m lateral, five selected randomized emitter placements were investigated. Two emitter points were placed near the inlet, one at the far end, and two in the center at one-third and two-thirds positions. The laterals were labeled as lateral one (L_1) and lateral two (L_2), and each lateral had seventeen emitter points. This results in a total of 34 emitter points on both laterals, with just 10 serving as focus points for the evaluation. To avoid clogging, the laterals were flushed before each test.

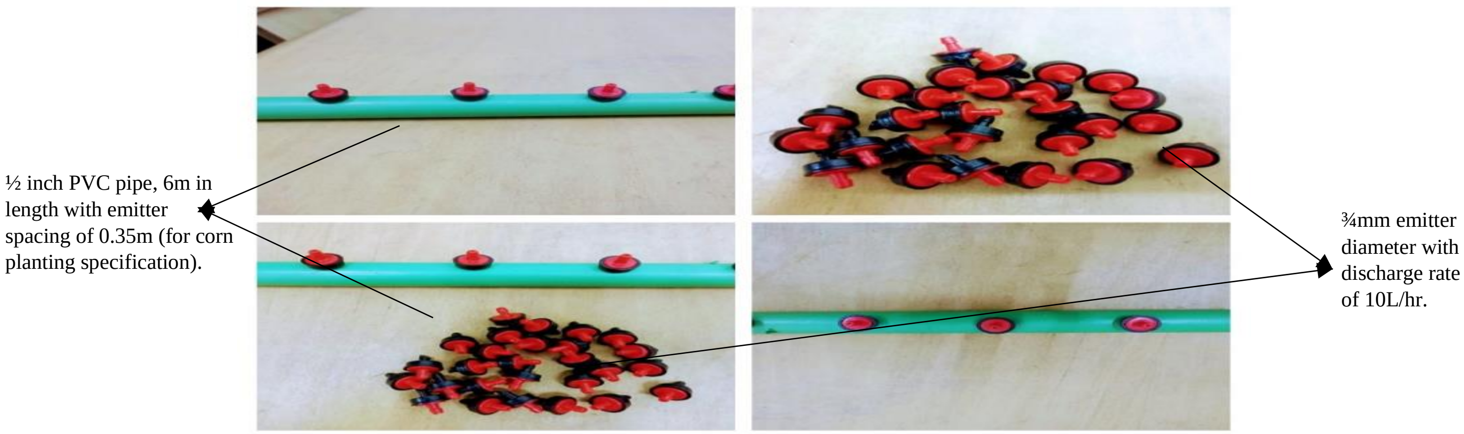

Figure 1: Pressure compensating (PC) drip emitters fitted in a polyvinyl chloride (PVC) pipe for corn planting specification.

Parameters used to Evaluate Drip Emitters

The following criteria were used to compare different drip irrigation products that operated at high and low OPH based on the obtained data in the studied area:

Average emitter discharge rate (Q_{var}): The Average emitter discharge rate (Q_{var}) is the average quantity of water emitted by each emitter per unit time, which is calculated as follows (as classified in Table 1):

$$Q_{var} = \frac{qmax - qmin}{qmax} \times 100$$

Where:

q_{max} = Maximum emitter flow rate

q_{min} = Minimum emitter flow rate

Table 1: Criteria for the evaluation of drip emitters based on the average emitter discharge rate.

Q_{var} Range	Classification
10% or less	Desirable
10% - 20%	Acceptable
Greater than 25%	Not Acceptable

*Adopted from ASAE EP405.1, 2000

Standard deviation of emitter flow rate (Sq):

$$Sq = \sqrt{\frac{1}{n-1}} \sum_{i=1}^{n} (qi - qvar)^2$$

Where:

n = Total number of emitters

q_i = flow rate of the emitter (10 L/h)

The coefficient of variation of emitter flow (Cv): Coefficient of Variation measures flow variability and is calculated by dividing the standard deviation by the mean. The coefficient of variation for each of a manufacturer's products is generally published (as classified in Table 2). *CV* can be written as:

$$CV = \frac{Sq}{qvar}$$

Table 2 Classification of coefficient of variation

Coefficient of Variation, *CV*	Classification
>0.4	Unacceptable
0.4 – 0.3	Acceptable
0.3 – 0.2	Very good
<0.1	Excellent

*Adopted from ASAE 46th Ed. EP 458, 1999

Uniformity coefficient (UC): The water application uniformity of a drip irrigation system was assessed using the ASABE uniformity coefficient formula, which is written as:

$$UC = 100[1 - \frac{1}{nqvar}\sum_{i=1}^{n}|qi - qvar|]$$

The Uniformity coefficient is as classified in Table 3

Table 3: Classification of Uniformity coefficient

Uniformity Coefficient, *UC* (%)	Classification
Above 90%	Excellent
90% - 80%	Good
80% - 70%	Fair
70% - 60%	Poor
Below 60%	Unacceptable

*Adopted from ASABE Standards EP 458,1999

Emission uniformity (EU): Emission Uniformity is calculated as the ratio of the average flow produced by 25% of the emitters with the lowest flow to the mean flow generated by all emitters (Classified in Table 4).

$$EU = [1.0 - \frac{1.27Cv}{\sqrt{n}}] \times (\frac{qmin}{qmax}) \times 100$$

Where: q_{max} – maximum emitter flow rate, q_{min} – minimum emitter flow rate, n – number of emitters, q_{var} – average discharge, q_i – flow discharge.

Table 4: Classification of Emission Uniformity

Emission Uniformity (EU) Ranges	Classification
> 90%	Excellent
80% - 90%	Good
70% - 80%	Fair
<70%	Poor

*Adopted from ASAE 1996(a)

2.4. Testing the Apparatus

For this study, a laboratory experiment was set up. A 50 L capacity container was used for the water supply. As shown in Fig. 2, a 6.0 m length of lateral with an internal diameter of ½ inch (0.0127 m) was used for this experiment. In this experiment, seventeen drip emitters with a design or manufacturing discharge rate of 10 L/h and a ¾ mm emitter diameter at a PC emitter interval of 0.35 m for corn planting specification were installed on each lateral. Five (5) distinct OPH (i.e., 1.60m, 1.40 m, 1.20 m, 1.00 m, and 0.80 m), five selected randomized emitter locations on each lateral were examined and was repeated three (3) times each. The emitters were kept dripping for three-time variations of 10, 20, and 30 minutes for all five OPH during the samples collection. In contrast, after turning on the valve, emitters were left to drip for 5 to 10 minutes to allow air to escape from the laterals. After ensuring that the final emitter at the laterals end had trickled out and no air was leaving from the laterals, samples were taken. The water collection time was designed such that around 500 to 1000 ml of water could be collected to compute the discharge rate per the minutes necessary.

2.5. Data Collection

During the data collection phase, the drip irrigation system was first stabilized at a known operating pressure head (OPH) to eliminate any air bubbles and ensure steady-state conditions. This initial step was critical in guaranteeing consistent water flow and pressure across all emitter points within the PVC lateral pipes, each measuring 6 meters in length and mounted on a wooden stand with adjustable heights ranging from 0.80 m to 1.60 m. This setup allowed for the simulation of varying pressure conditions relevant to agricultural settings. Catch cans, sized at 500 ml each, were strategically positioned beneath randomly selected emitter points on each lateral line. This selection ensured that the catch cans could capture the water emitted from the drip emitters without risk of overflow during the designated time intervals of 10, 20, and 30 minutes. The placement of these catch cans was meticulous to prevent any potential displacement or loss of collected water, thereby maintaining the integrity of the data collection process. Using calibrated stopwatches, the timing of water collection in each catch can began precisely when the first drop of water entered, ensuring accurate measurement intervals. At the end of each predetermined time interval, the stopwatch was stopped, and the exact time taken for water collection was recorded. Subsequently, the volume of water collected in each catch can was measured using calibrated beakers, providing precise quantitative data on water flow from each emitter point. Flow rates for each emitter point were calculated by dividing the volume of water collected by the respective time interval recorded. To ensure data accuracy and reliability, this calculation was repeated three times for each emitter point at each time interval. The average of flow rate across these replicates was then computed and recorded as the final value for each emitter point. Upon completion of data collection, all recorded measurements were compiled and analyzed comprehensively to assess the uniformity and overall performance of the pressure-compensating drip emitters under the various simulated pressure conditions. This analytical process adhered to the standards set by the American Society of Agricultural and Biological Engineers (ASABE, 1999) for uniformity testing using the catch-can method. The findings from this meticulous data collection and analysis provided valuable insights into the efficacy and reliability of the gravity-fed drip irrigation system evaluated in this study.

2.6. Data Analysis

An excel spreadsheet was used to organize the recorded flowrate of each sampled point in the system. The maximum flowrates; q_{max}, minimum flowrates; q_{min}, and average flowrates; q_{avg}, from each sample were used to compute their CV and EU. Tables will be used to present the data.

3.0. RESULTS AND DISCUSSIONS

3.1. Performance evaluation of 1.60 m pressure head

Variations in the Q_{var} of the 1.60 m OPH (Table 5) were observed to be 2.18%, 1.29%, and 1.53% for a dripping time of 10, 20, and 30 minutes, respectively. According to Bralts et al. (1987), a change in emitter flow rate of 10% or less is generally regarded desirable. The discharges from the 1.60 m OPH were desired for the various dripping time, meeting the criteria for evaluating drip emitters. The expected differences in the discharge of emitters or flow variability, CV which is the ratio of the standard of

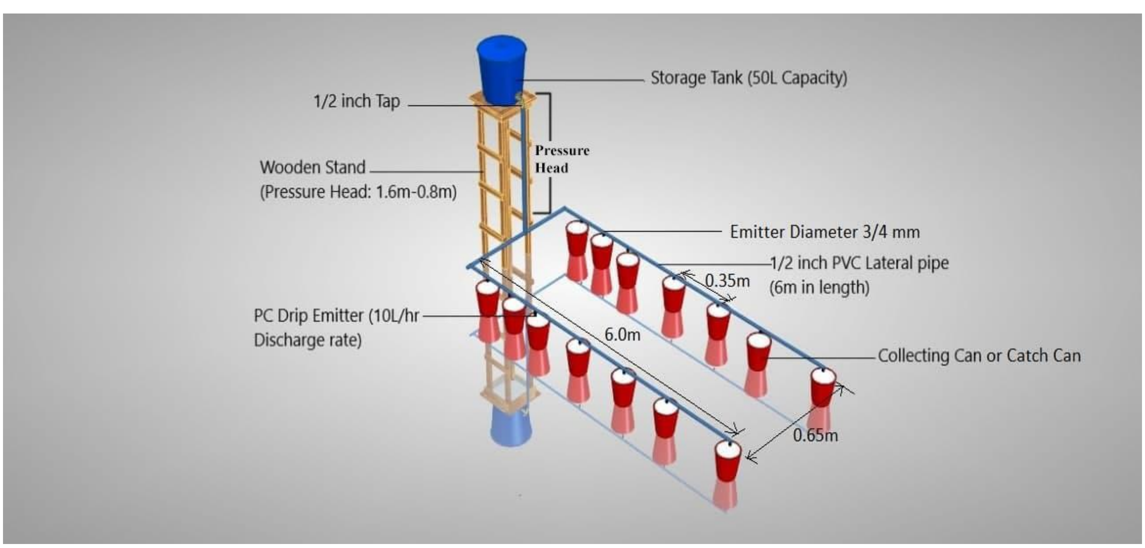

Figure 2: Layout of the test apparatus for discharge (Q_{var}) testing

the measured flowrate to the average flowrate were 0.0218, 0.0129, and 0.0153 for dripping time of 10, 20, and 30 minutes respectively. The classification of these values according to (ASABE, 2008R) shows that all flow variabilities were excellent. The uniformity of water delivery, *EU* by emitters in this experiment for the specified dripping time of 10, 20, and 30 minutes were 97.36%, 98.43% and 98.14% respectively. According to ASAE (1996), emission uniformities for 20 and 30 minutes were excellent for OPH of 1.60 m. *UC* values under this OPH were 89.45%, 80.18% and 83.68% (10, 20, and 30 minutes respectively) ranging between 80 – 90% which is good as reported by ASABE (1999) and this meets the desirable criteria for assessing drip emitters for a drip irrigation system.

3.2. Performance evaluation of 1.40 m pressure head

Variations in the Q_{var} of the 1.40 m OPH as shown in Table 6 were observed to be 6.17%, 6.61%, and 6.65% for dripping time of 10, 20, and 30 minutes, respectively. According to Bralts et al. (1987), a change in emitter flow rate of 10% or less is generally regarded desirable, and so all dripping time (10, 20, and 30 minutes) discharges were desirable and meets the criteria for evaluating drip emitters. The expected differences in the discharge of emitters or flow variability, *CV* which is the ratio of the standard of deviation of the measured flowrate to the average flowrate were 0.0617, 0.0661, and 0.0665 for dripping time of 10, 20, and 30 minutes respectively. The classification of these values according to (ASABE, 2008R) shows that all flow variabilities were average. The uniformity of water delivery, *EU* by emitters in this experiment for the specified dripping time of 10, 20, and 30 minutes were 92.57%, 92.05% and 91.99% respectively. According to ASAE (1996), *EU* for all dripping time were excellent for this OPH of 1.40 m. *UC* values under this OPH were 98.18%, 98.49% and 98.52% (10, 20, and 30 minutes respectively) all above 90% which is excellent as reported by ASABE (1999) and this meets the desirable criteria for assessing drip emitters for a drip irrigation system.

Table 5: Performance criteria for the 1.60m pressure head

TIME (minutes)	Q_{var} (%)	Classification	CV	Classification	EU (%)	Classification	UC (%)	Classification
10	2.18	Desirable	0.0218	Excellent	97.36	Excellent	89.45	Good
20	1.29	Desirable	0.0129	Excellent	98.43	Excellent	80.18	Good
30	1.53	Desirable	0.0153	Excellent	98.14	Excellent	83.68	Good

Q_{var}: average discharge, CV: coefficient of variation, EU: emission uniformity**,** UC: uniformity coefficient

3.3. Performance evaluation of 1.20 m pressure head

Variations in the Q_{var} of the 1.20 m OPH as shown in Table 7 were observed to be 27.25%, 9.09%, and 8.82% for dripping time of 10, 20, and 30 minutes, respectively. According to Bralts et al. (1987), a change in emitter flow rate of 10% or less is generally regarded desirable, and so 20–30 minutes discharge of 9.09% and 8.82% were desirable and meets the criteria for evaluating drip emitters while Q_{var} values for the 10 minutes was unacceptable. The expected differences in the discharge of emitters or flow variability, *CV* which is the ratio of the standard deviation of the measured flowrate to the average flowrate were 0.273, 0.091 and 0.0882 for dripping time of 10, 20, and 30 minutes respectively. The classification of these values according to ASABE (2008R) shows that the 20- and 30-minutes flow variability was average, with that of the 10 minutes being unacceptable. The uniformity of water delivery, *EU* by emitters in this experiment for the specified dripping time of 10, 20, and 30 minutes were 68.43%, 89.11% and 89.43% respectively. According to ASAE (1996), *EU* for 10 minutes was poor, and that of 20–30 minutes dripping time was good for this OPH. *UC* values under this pressure head were 98.14%, 99.71% and 99.60% (10, 20, and 30 minutes respectively) all above 90% which is excellent as reported by ASABE (1999) and this meets the desirable criteria for assessing drip emitters for a drip irrigation system.

Table 6: Performance criteria for the 1.40 m pressure head

TIME (minutes)	Q_{var} (%)	Classification	CV	Classification	EU (%)	Classification	UC (%)	Classification
10	6.17	Desirable	0.0617	Average	92.57	Excellent	98.18	Excellent
20	6.61	Desirable	0.0661	Average	92.05	Excellent	98.49	Excellent
30	6.65	Desirable	0.0665	Average	91.99	Excellent	98.52	Excellent

Q_{var}: average discharge, CV: coefficient of variation, EU: emission uniformity, UC: uniformity coefficient

Table 7: Performance criteria for the 1.20 m pressure head

TIME (minutes)	Q_{var} (%)	Classification	CV	Classification	EU (%)	Classification	UC (%)	Classification
10	27.25	Unacceptable	0.273	Unacceptable	68.43	Poor	98.14	Excellent
20	9.09	Desirable	0.091	Average	89.11	Good	99.71	Excellent
30	8.82	Desirable	0.0882	Average	89.43	Good	99.60	Excellent

Q_{var}: average discharge, CV: coefficient of variation, EU: emission uniformity, UC: uniformity coefficient

3.4. Performance evaluation of 1.0 m pressure head

Variations in the Q_{var} of the 1.0 m OPH (Table 8) were observed to be 17.35%, 12.22%, and 10.02% for dripping time of 10, 20, and 30 minutes, respectively. According to Bralts et al. (1987), a change in emitter flow rate of 10 – 20% is generally regarded as acceptable, and so dripping time of 10, 20 and 30 minutes were considered acceptable. The expected differences in the discharge of emitters or flow variability, *CV* which is the ratio of the standard of deviation of the measured flowrate to the average flowrate were 0.174, 0.122, and 0.100 for dripping time of 10, 20, and 30 minutes respectively. The classification of these values according to (ASABE, 2008R) shows that the flow variability for the 10 minutes dripping time was unacceptable, and that of 20 minutes was marginal with 30 minutes being average. This could possibly be because of a number of reasons. Firstly, rate of flow decreases with a decrease in OPH, and discharges from various emitters may not be as uniform as will be in other OPHs. And secondly, the length of lateral plays a role on water movement within the lateral. Uneven and ununiform flow of water through laterals could also affect the flow variability. Lastly, laterals susceptibility to clogging could also affect the flow variability and any of the above reasons can be a factor to the unacceptable *CV* values recorded for all three-dripping time under this OPH. The uniformity of water delivery, *EU* by emitters in this experiment for the specified dripping time of 10, 20, and 30 minutes were 79.53%, 89.45% and 88.01% respectively. According to ASAE (1996), *EU* for 20 and 30 minutes were good with a fair *EU* value from only the 10-minute dripping time for this OPH. *UC* values under this OPH were 98.75%, 99.47% and 99.99% (10, 20, and 30 minutes respectively) all above 90% which is excellent as reported by ASABE (1999) and this meets the desirable criteria for assessing drip emitters for a drip irrigation system.

Table 8: Performance criteria for the 1.00 m pressure head

TIME (minutes)	Qvar (%)	Classification	CV	Classification	EU (%)	Classification	UC (%)	Classification
10	17.35	Acceptable	0.174	Unacceptable	79.53	Fair	98.75	Excellent
20	12.22	Acceptable	0.122	Marginal	85.45	Good	99.47	Excellent
30	10.02	Acceptable	0.100	Average	88.01	Good	99.99	Excellent

Qvar: average discharge, CV: coefficient of variation, EU: emission uniformity**,** UC: uniformity coefficient

3.5. Performance evaluation of 0.80 m pressure head

Variations in the Q_{var} of the 0.80 m OPH as presented in Table 9 were observed to be 23.88%, 15.94%, and 9.93% for dripping time of 10, 20, and 30 minutes, respectively. According to Bralts et al. (1987), a change in emitter flow rate of 25% or more is generally regarded unacceptable, and all three-dripping time had discharges below 25% with 10 and 20 minutes being acceptable. A change in emitter flow rate of 10% or less is generally regarded desirable, and so the dripping time of 30 minutes discharge was desirable and meets the criteria for evaluating drip emitters. The expected differences in the discharge of emitters or flow variability, *CV* which is the ratio of the standard of deviation of the measured flowrate to the average flowrate were 0.239, 0.159 and 0.0993 for dripping time of 10, 20, and 30 minutes respectively. The classification of these values according to ASABE (2008R) shows that the flow variability for the 10 – 20 minutes dripping time were unacceptable for values of *CV* obtained with 30 minutes being average. The uniformity of water delivery, *EU* by emitters in this experiment for the specified dripping time of 10, 20, and 30 minutes were 72.16%, 81.14% and 88.13% respectively. According to ASAE (1996), *EU* for 20 and 30 minutes were good with a fair *EU* value from only the 10-minute dripping time for this OPH. *UC* values under this OPH were 98.29%, 98.90% and 99.98% (10, 20, and 30 minutes respectively) all above 90% which is excellent as reported by ASABE (1999) and this meets the desirable criteria for assessing drip emitters for a drip irrigation system.

3.6. Average (Qvar) emitter discharge flow

The laboratory experiment on the drip irrigation system was carried out at various OPHs (1.6 m - 0.80 m, at 0.2 m interval) for two laterals of PVC pipes to test different drip irrigation system hydraulic characteristics. Drip emitter discharges were measured and recorded at various OPHs at a 10 L/h discharge rate for 10, 20, and 30 minutes, respectively as shown in Table 10.

Table 9: Performance criteria for the 0.80 m pressure head

TIME (minutes)	Q_{var} (%)	Classification	CV	Classification	EU (%)	Classification	UC (%)	Classification
10	23.88	Acceptable	0.239	Unacceptable	72.16	Fair	98.29	Excellent
20	15.94	Acceptable	0.159	Unacceptable	81.14	Good	98.90	Excellent
30	9.93	Desirable	0.0993	Average	88.13	Good	99.98	Excellent

Qvar: average discharge, CV: coefficient of variation, EU: emission uniformity, UC: uniformity coefficient

Table 10: Average emitter discharge.

Pressure Head (m)	Average Discharge (L)					
	10 minutes		20 minutes		30 minutes	
	Line 1	Line 2	Line 1	Line 2	Line 1	Line 2
1.60	1.667	1.663	3.333	3.325	4.995	5.000
1.40	1.550	1.560	3.200	3.220	4.750	4.780
1.20	1.433	1.440	3.167	3.186	4.500	4.529
1.00	1.317	1.323	3.033	3.053	4.350	4.379
0.80	1.200	1.207	2.900	2.920	3.900	3.929

The experiment was repeated three times for each of the five OPHs at the stated dripping periods of (10, 20, and 30 minutes). This was done in order to obtain a more precise value for catchments of average emitter discharge flow rate. The discharge for the selected emitter point was determined using the average discharge value obtained after the third test. Table 10 shows a summarized result of all values collected for the experiment, with a final average value taken for all discharges computed for the five selected randomized emitter locations on each lateral and recorded for each OPH under the various dripping time.

Generally, as the OPH was reduced or decreased, values obtained for Q_{var} for the other OPHs were increasing. Increasing Q_{var} or high values for Q_{var} only yielded unacceptable drip emitter characteristics as reported by Bralts et al. (1987). For desirable values of Q_{var}, OPH should be increased. This applies also to the *EU* whose values decreased as OPH was reduced. This infers that, excellent *EU* will be obtained with a relatively high OPH, and close to poor or unacceptable *EU* will be obtained for lower OPH. Another reason for low *EU* along laterals is clogging of emitters. The primary components of the clogging process are suspended particles from the water. These particles, when combined with bacterial biofilms, can decrease emitter flow by forming obstacles in the flow channel (Oliver et al., 2014). The *UC* was excellent for all OPHs and meets the criteria for assessing drip emitters for a drip irrigation system.

4.0. CONCLUSION

This study described five OPHs (1.60, 1.40, 1.20, 1.00, and 0.80 m) for flow estimates and performance criteria for evaluating drip emitters in a basic drip irrigation system. The results of the experiment indicated that decreasing or reducing the OPH resulted in unsatisfactory Q_{var} values for the 0.80m OPH. OPH should be raised to achieve appropriate emitter flow fluctuations. *EU* values obtained after the experiment show another influence of OPH on water distribution. *EU* values discovered to be decreasing and diverging from the desired as OPH was lowered. This implies that a reasonably high-OPH will yield a good *EU*, whereas lower-OPH will yield a substandard or unsatisfactory *EU*.

The water distribution was also affected by dripping time (10, 20, and 30 minutes). *EU* climbs to the permissible range as dripping time passes. Allowing the tap to run for at least half an hour (30 minutes) will provide greater and more effective water distribution uniformity.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

REFERENCES

ASABE Standards. (2008) Design and installation of micro-irrigation systems. 50th Ed. EP 405. St. Joseph, Michigan: ASABE.

ASAE (2000) Design and installation of micro irrigation systems. ASAE EP405.1 DEC99. In: ASAE Standards, St. Joseph, Michigan.

ASABE Standards. (1999) Field evaluation of micro-irrigation systems. 46th Ed. EP 458. St. Joseph, Michigan: ASABE.

American Society of Agricultural Engineers and Engineering Practice Standard. (1996a) Design and installation of Micro Irrigation Systems, EP405.1: St. Joseph, Michigan., USA.

Asenso, E & Li, J & Chen, H.-B & Ofori, E & Issaka, F & Brako, B. (2014) Head and lateral length on water distribution uniformity of a PVC drip irrigation system. African Journal of Agricultural Research, 9(30), 2298–2305. https://doi.org/10.5897/ajar2013.7468.

Bralts, V.F & Edwards, D.M & Wu, I.P. (1987) Drip irrigation design and Evaluation Based on Statistical Uniformity Concepts. Advances in irrigation. 4:67-117.

Ella, V. B & Baños, P & Reyes, M.R & Yoder, R & Tech, V. (2008) Effect of Hydraulic Head and Slope on Water Distribution Uniformity of a Low- cost Drip Irrigation System. 01.

Herman, E.S & Ab Razak M.S. (2014) Hydraulic Performance and Modelling of Pressurized Drip irrigation system. 1–88.

Jusoh, M.F & Adnan, N & Abdul, M & Katimon, A. (2020) Performance Evaluation of Drip Irrigation System and Water Productivity (WP) of Rock Melon Grown inside Netted Rain House Shelter. IOP Conference Series: Earth and Environmental Science, 549(1). https://doi.org/10.1088/1755-1315/549/1/012094

Oliver, M.M.H & Pezzaniti, D & Hewa, G.A. (2014) Emitter clogging in a reclaimed water irrigation scheme with controlled suspended load. International Journal of Sustainable Development and Planning, 9(6), 847–860. https://doi.org/10.2495/SDP-V9-N6-847-860.

Raphael, O.D & Amodu, M.F & Okunade, D.A & Elemile, O.O & Gbadamosi, A.A. (2018) Field evaluation of gravity-fed surface drip irrigation systems in a sloped greenhouse. International Journal of Civil Engineering and Technology, 9(10), 536–548.

Ravi, K & Gahlot, V.K & Saxena, C.K. (2016) Pressure Compensated Micro Sprinklers: A Review. International Journal of Engineering Research, V5(01), 237–242. https://doi.org/10.17577/ijertv5is010184

Shock, C.C. (2013). Drip Irrigation: An Introduction. March.

Soomro, K.B & Rind, J & Ahadkolachi, A & Nizamani, F.K & Soomro, A.F. (2013). Evaluate the performance of drip irrigation and discharge of emitters at Coastal area of GadapSindh. 2(9), 259–275.

Tayel, M.Y & Pibars, S.K & Mansour, H.A. (2019). The impact of different closed drip irrigation networks and dripper type on pressure distribution along lateral lines and uniformity. Plant Archives, 19, 548–553.