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HYDRAULIC PERFORMANCE OF DIFFERENT EMITTERS UNDER VARYING LATERAL LENGTHS

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ABSTRACT

Despite the acute shortage of water for irrigation and its enormous domestic consumption, the water users in Pakistan continue using water injudiciously. This has decreased the overall irrigation efficiency up to 30%. In order to enhance the irrigation efficiency, micro irrigation methods such as drip, sprinkler, and bubbler irrigation are being used in the developed countries. Among these, the drip irrigation method is considered as the most efficient method requiring only 20 to 30% of water as compared to conventional methods. However, the performance of drip irrigation system is based on the proper design of emitters, spacing of emitters and proper spacing between delivery lines etc. But the design of emitters plays a prime role in uniform distribution of water on the field. Thus, keeping the importance of design of emitters the present study was conducted on the hydraulic performance of different emitters under varying lateral lengths to evaluate emitter discharge and emission uniformity. An experiment was conducted at Lal Baksh Farm near Chotta Gate, Gadap town Karachi to study the performance of emitters under varying lengths of laterals to evaluate emitter discharge and emission uniformity. Two types of emitters (pressure compensated and micro tube) with varying length of laterals were tested. Results suggest that the pressure compensated emitters performed well as no significant differences between average discharges were found between locations as well as between lateral lengths. They were able to control the pressure variation along the lateral length whereas the micro tube type emitters were unable to compensate such variations hence the discharges were significantly different along the lateral length. Emission uniformity with pressure compensated type emitters was 91.2% for a lateral of 57.2 m length while it was 88.2% for the lateral of 71.2 m length. Micro tube type emitters of 57.2 m length produced 82.8% emission uniformity while it yielded to 79.4% with lateral of 71.2 m length. Results of the study revealed that the pressure compensated emitters perform better and manage the pressure losses at different locations along the laterals length, hence could be preferred over micro tube emitters.

Keyword: Drip irrigation, emitters/drippers, lateral lengths, emission uniformity.

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INTRODUCTION

Pakistan possesses one of the world's most well-recognized and largest contiguous irrigation water delivery systems; which is ranked 5th in the world and 3rd in the Asia. Despite having such a well established irrigation water delivery system, total demand for water for agricultural, industrial and domestic use is greater than the supply, which limits its availability to the growers especially those at the tail-reaches. Producers apply water through traditional methods which often have an overall efficiency of less than 30% (Ishfaq, 2002). This efficiency can be improved by reducing the field application losses so that water could be utilized in producing vegetables, forage and grain. One way to accomplish this is by replacing the traditional flood irrigation methods with modern high efficiency irrigation methods such as drip, sprinkler, subsurface and bubbler. These methods not only have high application efficiency but they produce higher yields. Sharma (2001) reported 33 to 37% greater yields with sprinkler irrigation method compared to that of with traditional check basin and border strip irrigation methods. According to Yildrin and Korukcu (2000) drip irrigation generally achieves better crop yield and balanced soil moisture in the active root zone with minimum water losses. On the average, drip irrigation saves about 70 to 80% water when compared to conventional flooding or furrow irrigation methods (Ishfaq, 2002). This water conservation is only possible when water is uniformly discharged through emitters. Drip irrigation system either surface or subsurface is designed to provide water only near to root zone that maintains the moisture to its optimum level. The system irrigates only a portion of the land surface which limits soil evaporation, reduces weed growth, and minimizes interruption of cultural operations. In order to maintain optimum moisture level in the root zone, it is necessary to apply frequent applications of small amounts of water. The small amounts of water improve the water-use efficiency (WUE), provide greater yield and enhances crop quality. Uniform distribution of water means that all the plants have equal access to water. This is only possible when accurate emitter manufacturing is provided by the company. However, it is difficult to maintain such precision during production due to complexity of emitter design and their individual components. During the process of emitter manufacturing, some factors such as changes in production temperature, non-uniform mixing of raw material, and mold damage may result in defective emitters. Also, the parts made from the materials used to achieve flushing action and pressure reparation are difficult to manufacture with consistent dimensions.

Ideally, each emitter would deliver exactly the same amount of water regardless of where it is positioned in the field. In reality, emitter discharge is variable along a lateral line in a drip irrigation system. Solomon (1979) reported that manufacturing variations, pressure differences, emitter plugging, aging, frictional head losses, irrigation water temperature changes, and emitter sensitivity result in flow rate variations even between two identical emitters (Mizyed and Kruse, 2008). Also, the emitter operating characteristics tend to fluctuate over passing time. Thus flow might change even with a constant pressure. In a poorly designed system, the operator may not able to get uniform distribution of water which may result either in under irrigation or over irrigation. Under both cases, plants will either suffer the dry stress or experience wet stress. Through a properly designed drip system, a uniformity co-efficient of at least 85% is considered appropriate for standard design requirements. Such a high uniformity coefficient is only possible through properly designed emitters (Al-Amound, 1995) that provide steady discharge to all emission points. However, the distribution uniformity is a function of several factors including hydraulic head and slope of lateral and sub-main lines. The distribution uniformity substantially decreases at slopes steeper than 30% (Ella *et al.*, 2009).

Though the drip system slowly and partially wets the soil near the plant root zone, but it is practically difficult to apply the equal amount of water to all plants within a field especially at tail reaches. Therefore, in most cases, even a well designed system gives poor uniformity as a consequence the yields are pretentious (Bhatnagar and Srivastava, 2003). Since, frequent application near the plants is necessary (Youngs *et al.,* 1999), the conveyance and the other conventional losses such as deep percolation, runoff and soil water evaporation are minimal as water is conveyed through a network of pipes.

A drip irrigation method comprises pumping unit, a mixing chamber, main line, sub main, laterals and emitters. The main line carries water from pumping unit to sub main; sub main conveys water from main to laterals; the laterals are spread in the field along with the rows of plants. The emitters/drippers are then fixed in the laterals to supply water to the application points of requirement, generally near the plant. There are several types of emitters/drippers available in the market. The main purpose of these emitters/drippers is to apply nearly the same amount of water to each plant throughout length of lateral. However, this can not be possible because the water carrying capacity of laterals decreases with the increase in length due to friction. Therefore, a well designed drip irrigation system should ensure relatively same amount of water to each plant along the total length of lateral line. The discharge rates for most non-pressure compensating emitters are either greater or less than expected. A coefficient of manufacturing variation integrates the discharge fluctuations along a lateral for a given operating pressure. Its values are found to be greater for pressure compensating emitters than for non-compensating emitters (Özekici and Sneed, 1990). Present field study was conducted to evaluate the performance of emitters/drippers under varying lengths of laterals.

MATERIALS AND METHODS

A field experiment was conducted at Lal Baksh Farm near Chotta Gate, Gadap town Karachi. The soil at the experimental site was sandy loam to silty, the bulk density ranged between 1.18 to 1.32 g cm^{-3}, and the average infiltration rate ranged from 9.6 to 1.62 mm hr^{-1}. The common crops grown in the area were jujube, lemon, papaya, chilies, tomatoes, and cucumber. Considering the importance of jujube and papaya crops in area the study was conducted to evaluate performance of emitters/drippers under varying length of laterals in terms of emission uniformity for jujube crop. The entire research area (137.2 m x 121.9 m) was divided into four hydro zones denoted as H1, H2, H3, and H4 as shown in Figure 1. Two types of emitters *viz.* Pressure compensated and Micro tube with varying length of laterals were tested. In two hydro zones H1 and H3 pressure compensated type emitters were plugged in the laterals, while the length of the laterals was kept 57.2 m designated as L1 and 71.2 m designated as L2 respectively. Similarly in remaining two hydro zones i.e. H2 and H4, micro tube type emitters were installed in the laterals, and the length of laterals was kept similar to H1 and H3 respectively. In order to measure the emission uniformity, six trees located at the head, middle and tail end along the each lateral were selected and these were denoted as P1, P2 and P3 respectively. Each tree was surrounded by four emitters; hence discharge measurements were taken on all four emitters. Collectors were placed under each emitter to collect the volume of water delivered per unit of time. The collected water was measured using a graduated cylinder.

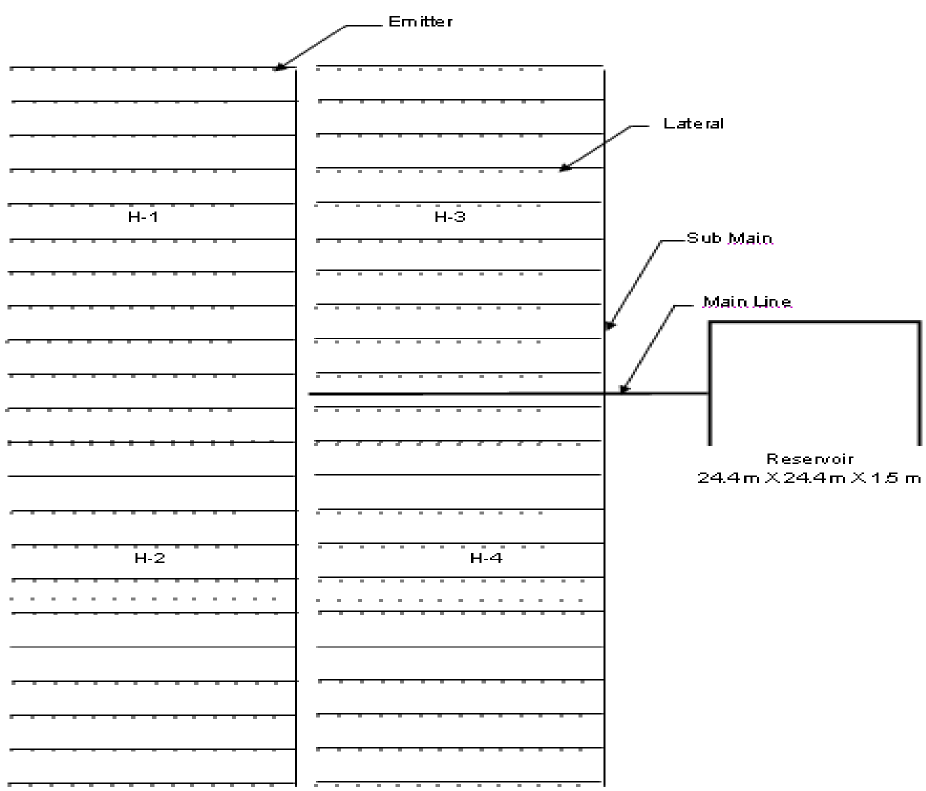

Figure 1. Layout of the experimental plot

Uniformity Coefficient (Uc)

Ability of an irrigation system to distribute water equally throughout the field is referred to as uniformity. However, it is nearly impossible to have 100% uniformity of water distribution across the irrigated area due to differences in emitter delivery rates. From the irrigation efficiency point of view, both situations can result in the reduction of crop yield or quality, due to dry water stress or excess application. Thus, uniformity plays a vital role in selection, design, and management of the irrigation systems. One measure of drip irrigation uniformity is to calculate the uniformity coefficient of a system using the equation (Mosh, 2006):

$$U_C = 100 - \left(80\ x \frac{S_d}{V_{avg}} \right)$$

Where,

U_C = Uniformity coefficient (%),

S_d = Standard deviation of observed emitter flow,

V_{avg} = Average volume collected ml.

Emission Uniformity (EU)

Another measure of emitter uniformity (EU) is typically used to evaluate manufacturing quality of emitters. The EU is the ratio between the average discharge in the quarter receiving less water and the average discharge at the system level. It is used to describe the predicted emitter flow variation along a lateral line and can be assumed as synonymous to that of distribution uniformity (DU).

The following formula was used to calculate Emission Uniformity (Keller and Bliesner, 1990).

$$\text{EU} = 100\ [1.0 - 1.27 - \frac{C_v}{\sqrt{n}}] \frac{q_i}{q_{av}}$$

Where;

$$C_v = \frac{\sigma}{q_{av}} \times 100$$

And

$$\sigma = \frac{\sqrt{\sum_{i=1}^{n}\left(qi - qav\right)^2}}{n}$$

C_v = Coefficient of variation

σ = Standard deviation

n = No. of emitters

q_i =Minimum flow, ml sec^{-1}

q_{av} = Average flow, ml sec^{-1}

RESULTS AND DISCUSSION

Discharge measurements under pressure compensated emitter

The average discharges under pressure compensated emitters were taken for two lateral lengths i.e. 57.2 m, 71.2 m and results are illustrated in Figures 2 and 3, respectively. For the lateral having 57.2 m length, the average discharge at P1 was 0.0259 m^3 h^{-1}; it slightly reduced to 0.0239 m^3 h^{-1} for the emitters located at P2 and 0.0232 m^3 h^{-1} for those located at P3, however, the average discharge remained quite consistent for each location. The reduction in the pressure along the lateral length is anticipated because the pressure at the head of lateral was greater as compared to the middle and tail end; also the head losses due to friction might have affected the discharges towards the middle and subsequently at the tail end. The average discharges for the longer laterals (71.2 m) are depicted in Fig 3. Almost similar trends those with smaller laterals were observed. As anticipated, the discharges towards the middle and the end reduced. The average discharge for emitters located at P1 was 0.0263 m^3 h^{-1}, while it slightly reduced to 0.0244 m^3 h^{-1} and 0.0234 m^3 h^{-1} at P2 and P3, respectively. Comparison between two lateral lengths suggests that the discharges with longer lateral are slightly greater at all measurement locations as compared to laterals with shorter lengths. Statistical analysis was performed to identify differences between means for locations along each lateral length. The analysis suggest that the means for location and lateral length were non-significant ($p>0.05$) as shown in Table 1, which indicates that pressure compensated type emitters managed the pressure losses at different locations along the laterals length.

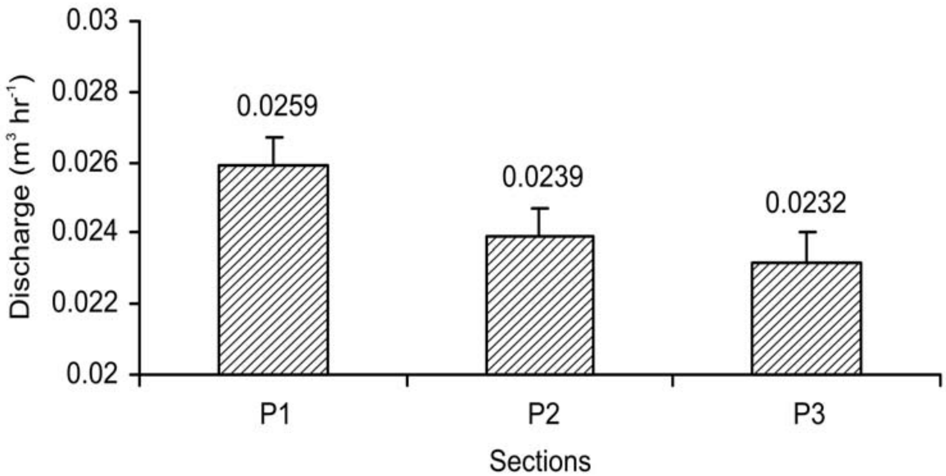

Figure 2 Average emitter discharge rates (m^3hr^{-1}) for pressure compensated emitters positioned 0, 28.6 and 57.2 m from the lateral inlet.

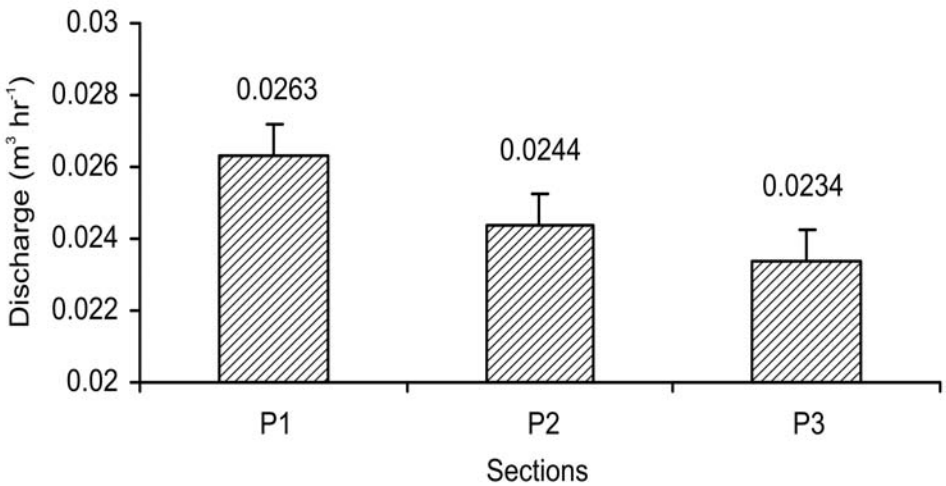

Figure 3 Average emitter discharge rates (m^3 h^{-1}) for pressure compensated emitters when the length was 71.2 installed 0, 35.6 and 71.2 m from the lateral inlet.

Discharge measurements under micro tube type emitters

The average discharges using micro tube type emitters for two lengths i.e. 57.2 m and 71.2 m are given in Fig. 4 and 5 respectively. The average discharge recorded for emitters located at P1 was 0.0274 m^3 h^{-1}, 0.0239 m^3 h^{-1} at P2 and 0.0218 m^3 h^{-1} at P3 for the lateral with 57.2 m length (Fig. 4). This is anticipated because the pressure at the head of lateral remains slightly higher as compared to the middle and tail end due to head losses. The average discharges for the laterals with 71.2 m length are portrayed in Fig. 5. The results suggest that the average discharge at P1 was 0.0277 $m^3 h^{-1}$, which remarkably reduced to 0.0238 and 0.0210 $m^3 h^{-1}$ at P2 and P3, respectively. As anticipated, the discharges towards the middle and the end reduced. Such results are attributed due to the lower pressure, which may have been responsible for the differences in emitter flow rate located at those locations. The statistical analysis was performed to find the differences between the means of locations along the lateral length. The analysis suggest that the means for locations were significantly different ($p>0.05$) as given in Table 1. Comparison between two types of emitters was made on the basis of discharge variations through them. The results suggest that the pressure compensated emitters performed well as no significant difference between average discharges were found between locations as well as between lateral lengths. While, significant difference between discharges through micro tube type emitters were observed for locations as well as for lateral lengths. These results suggest that the pressure compensated emitters were able to control the pressure variation whereas the micro tube type emitters were unable to compensate such variations hence the discharges reduced towards to the tail end. It could be concluded that for better performance pressure compensated emitters could be used.

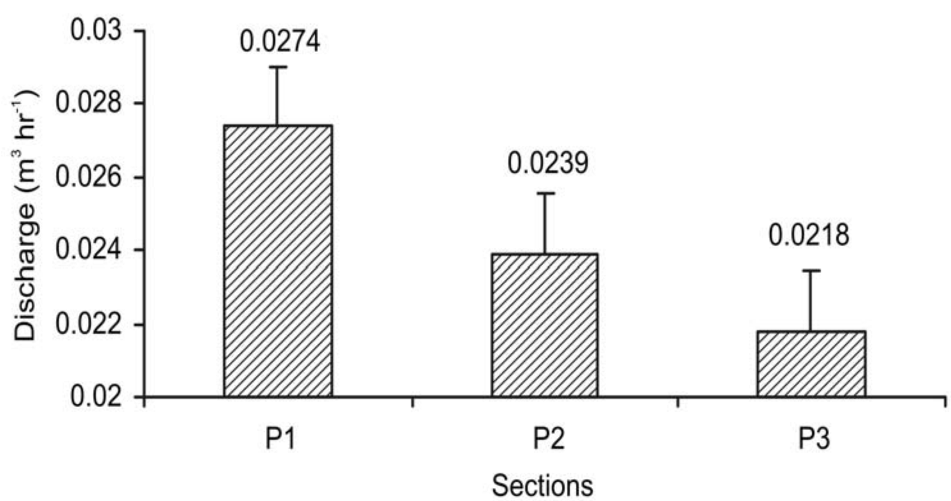

Figure 4. Av. discharges ($m^3 h^{-1}$) under micro tube emitter when the length of lateral was 57.2 m.

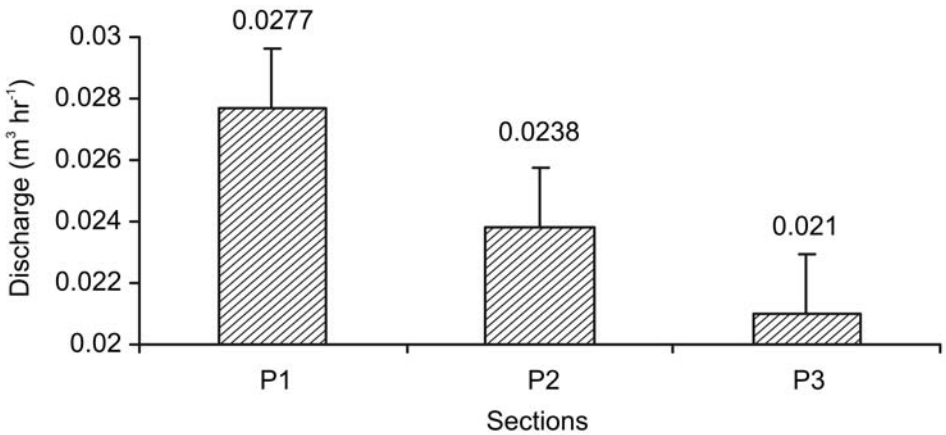

Figure 5. Av. discharges (m^3 h^{-1}) under micro tube emitter when the length of lateral was 71.2 m.

Table 1. Analysis of variance (ANOVA) of the data.

Source	DF	SS	MS	F	P
Length	1	2.072E-06	2.072E-06	1.57	0.2205
Location	2	1.057E-04	5.287E-05	39.96	0.0000
Length*Location	2	6.207E-06	3.104E-06	2.35	0.1131
Error	30	3.969E-05	1.323E-06		

Table 2. Mean values of both types of emitters with significant values.

Pressure Compensated Emitter				Micro Tube Emitter			
L1		L2		L1		L2	
P1	0.0259*	P1	0.0263*	P1	0.0274*	P1	0.0277*
P2	0.0239	P2	0.0244	P2	0.0239	P2	0.0238
P3	0.0232	P3	0.0234	P3	0.0218	P3	0.021

* Significant

Uniformity Coefficient and Emission uniformity

Uniformity Coefficient was calculated for pressure compensated and micro tube type emitters with 57.2 m and 71.2 m lateral lengths and results are plotted in Figure 6. The Uniformity Coefficient observed for lateral with 57.2 m length was about 95.8 while it was 95.2 for the lateral with 71.2 m length under pressure compensated emitters. Whereas, the Uniformity Coefficient for the micro tube type emitters was 92.0 and 90.6 with laterals having 57.2 m and 71.2 m lengths, respectively.

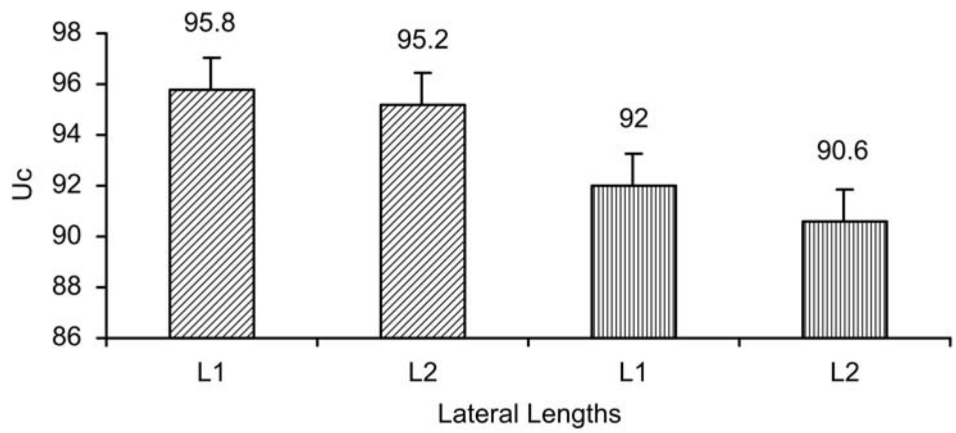

Figure 6. Uniformity Coefficient for pressure compensated and micro tube type emitters with 57.2 m and 71.2 m lateral lengths.

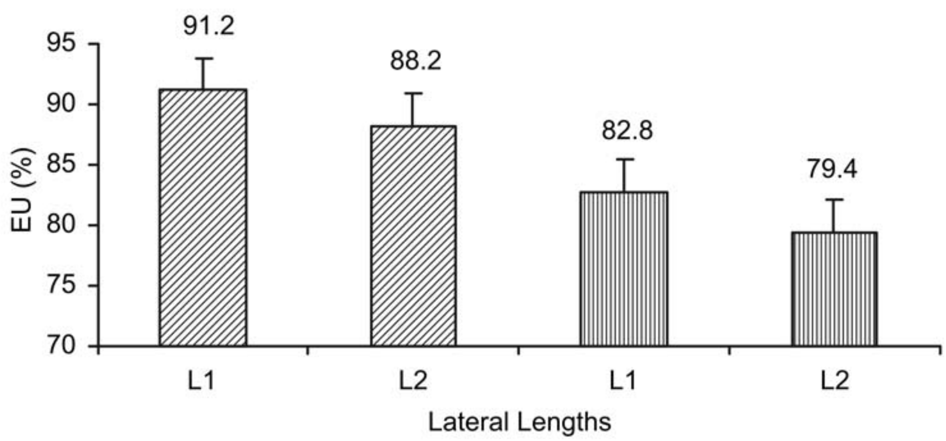

Figure 7. Emission uniformity (%) for pressure compensated and micro tube type emitters with 57.2 m and 71.2 m lateral lengths.

Similarly the Emission Uniformity was calculated for pressure compensated type emitters with 57.2 m and 71.2 m lateral lengths and results are plotted in Figure 7. The emission uniformity observed for lateral with 57.2 m length was about 91.2% while it was 88.2% for the lateral with 71.2 m length under pressure compensated emitters. Whereas, the emission uniformity for the micro tube type emitters was 82.8 and 79.4% with laterals having 57.2 m and 71.2 m lengths, respectively. These results suggest that the pressure compensated type emitters performed better with higher emission uniformity as compared to micro tube type emitters. Based on the findings of this study it is suggested that the drip installation companies as well as farmers should prefer the systems with pressure compensated type of emitters, which would give better uniformity.

Almost similar results were obtained by George *et al.* (1998); however they recommended that the lateral flow must be considered for the design of drip emitter.

CONCLUSION

A study was conducted to evaluate the performance of pressure compensated and micro tube emitters. The following conclusions can be drawn from this study.

Results of this study suggest that the pressure compensated emitters performed well as no significant differences between average discharges were found between locations as well as between lateral lengths. They were able to control the pressure variation along the lateral length whereas the micro tube type emitters were unable to compensate such variations hence the discharges significantly different along the lateral length.

The discharge towards the middle and the end decreased in magnitude for both emitter types however, the flow rates were significantly different only for micro tube emitters. Such results are attributed due to the lower pressure, which may have been responsible for the differences in emitter flow rate located at those locations.

Uniformity Coefficient using pressure compensated type emitters was 95.76 for a lateral having 57.2 m length while it was 95.206 for lateral with 71.2 m length. Micro tube type emitters having 57.2 m length produced 92.0 Uniformity Coefficient while it yielded to 90.57 with lateral having 71.2 m length**.**

Emission uniformity using pressure compensated type emitters was 92.21% for a lateral having 57.2 m length while it was 88.16% for lateral with 71.2 m length. Micro tube type emitters having 57.2 m length produced 82.8% emission uniformity while it yielded to 79.4% with lateral having 71.2 m length**.**

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