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HYDRAULIC PERFORMANCE ANALYSIS OF IN-LINE DRIPPERS

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Abstract

The ultimate purpose of the study is to reveal the reacts of in-line drippers' hydraulic performance emerging from the differences in the production process and the different technical features to flow changes; however, the drippers were produced in different companies at different rates of flow and technical features.
In order to reveal the relationship of drippers' pressure-flow, 3 different types of inline drippers have been used 51 pieces of drippers have been selected for each type of drippers and totally 153 tests have been carried out. Tests have been performed 0.5, 1, 1.5 and 2.0 atm pressure values. At the end of the research, it has been proved that the relationship of in-line drippers and pressure-flow is in directed proportionate. The results obtained from the following coefficiency tests; Manufacturing Variation (CVm), the Emission Uniformity (EU), Christiansen Uniformity (Cu) and Statistical Uniformity (Us), have showed that these coefficiencies have been observed higher (perfect rank) in pressure unregulated in-line drippers than the other types of drippers.

Key words: *In-line Drippers, Hydraulic Performance Analysis, Flow Rate-Pressure Relationship.*

INTRODUCTION

The drippers are the most important elements of the drip irrigation system which are used to give the roots of the plants required amount of water within a specific time period and with a defined pressure. Pressured water in the lateral pipes passes to the dripper where energy of the water decreases considerably due to the friction while it is advancing through the flow line. Water gets out of the dripper with a very small flow rate and infiltrates to the soil that is why drippers should be chosen very carefully.
The efficiency in the drip irrigation systems are dependent on the equivalence of the flow rate of the drippers. Therefore all the drippers in a system should ideally distribute water evenly (Ozekici and Bozkurt, 1996). The variation between the flow rates of the drippers must remain within particular limits in order for a high efficiency irrigation system. Otherwise the expected high performance of the system would not be reached (Korukcu and Yildirim, 1984). The structural differences, of the drippers are significant factors limiting efficiency of the irrigation systems which create flow rate inconsistency among the drippers that should essentially have identical flow rates. (Ozekici and Bozkurt, 1996). Drippers are the most important factors affecting the drip irrigation system both economically and in terms of functional performance. Therefore while conducting performance analyses of the system, priority should been given to determine the appropriate dripper models.
The change of the flow rates of the drippers are resulted from many factors like hydraulic changes and performance changes of drippers (Tüzel, 1993). The flow rate of the drippers may change significantly according to the pressure. In a drip irrigation system that is composed of pressure regulated drippers, all the single drippers having higher pressure values will make it possible to quench in a stable flow rate regardless of the system pressure (Demir, 1992). Drippers are the most sensitive units of the drip irrigation system which may partly or completely be obstructed as they have very small water canals. These obstructions may block the consistent flow of water in the system (Tüzel and Anaç, 1991).
The aim of this study is to analyze the flow rate - pressure connections and hydraulic performance of the different in-line drippers

under different system pressures and to provide information to the users regarding the in-line drippers that can be found in the market.

MATERIALS AND METHODS

This research is conducted in the Biosystem Engineering laboratories of the Faculty of Agriculture at Kahramanmaraş Sütçü Imam University (KSU) in order to evaluate the flow rate - pressure connections and the hydraulic performances of different dripper types displayed in different pressures. City water supply was used in the research to prevent the obstructions of the drippers during the experiments. Water was filled to a 40 liter tank with the help of a hose and the water circulation in the system was ensured from this tank. Water used in the experiment was provided through a water pump of 0.5 kW that was located between the tank and the main pipeline. Support structure is approximately 100 cm higher from the ground and consists of 3 sections. Water tank is located at the bottom while the pump and control unit was in the middle and the laterals are on the top. Laterals were located approximately 25 cm above the support structure as graduated bowls were positioned under the laterals in order to collect water. The length of the laterals is 80 cm in average and they were fixed, using clips till the end of the support structure to keep the elevation of the laterals steady. 3 lateral pipelines were echeloned at 25 cm intervals and there is 1 dripper on each lateral. The main pipe was made of 32 cm PPRC (polypropylene random copolymer). There were valves on the pipeline that were used to control the flow of the lateral lines and manometers that were used to monitor the system. Teflon band and clips were used to prevent water outlet leaks from the connection points of the experimental system that may happen as a result of high pressure. To evaluate system pressure 4 units of manometers with a capacity of 6 kg cm^{-2} were used. 3 of these manometers were used at the beginning of laterals to assess the pressure of the laterals and 1 of them was located on the pump to assess the system pressure. Moreover a filter (150 meshes) was installed to the system after the pump. 3 different types of in-line drippers that are widely used in our country were used in the experiment and the features of these drippers are given in Table 1.

Table 1. Features of the drippers used in the experiment

Dripper Type	Kind of Dripper		Flow-Rate (L/h) (1.0 Atm)
A	In-line	Pressure unregulated	2.0
B	In-line	Pressure unregulated	4.0
C	In-line	Pressure regulated	2

All the lateral pipes used in the experiment were circular PE with a 16 mm diameter. 51 units from each 3 kinds of the drippers were tested. The flow rate of the drippers were chosen among 2 L h^{-1} and 4 L h^{-1} that are used widely in the market. In-line drippers were chosen among those having minimum 40 cm as dripper distance in order to keep 1 dripper on the lateral in the experiment.

Experiments were conducted at 0.5, 1.0, 1.5 and 2.0 atm by getting results from the manometers that were located on each lateral. The flow rate measurements were made with the graduated bowls. During the experiments, the temperature of water in the tank was kept stable at 24-26^{o}C.

Using the flow rate values measured from each dripper, the coefficient dependent to flow regime (x), the flow coefficient (k), the correlation coefficient (r), the significance values showing the importance of the difference between adj R^2 showing the flow rate - pressure cohesion and flow rates and manufacturing variation (CVm), the Statistical Uniformity (Us), the Emission Uniformity (EU) and Christiansen Uniformity (Cu) coefficients were calculates in the experiment. The classifications of the drippers were done according to ASAE standards shown in Table 2.

Table 2. Proposed Limits of CVm, Us and EU coefficients (ASAE, 2002)

Accepted Class	CVm (%)	Us (%)	EU (%)
Excellent	5	100-95	100-94
Good	5-7	90-85	87-81
Average (in the limit)	7-11	80-75	75-68
Poor (very bad)	11-15	70-65	62-56
Unacceptable	>15	<60	<50

RESULTS AND DISCUSSIONS

x, k, r, $\mathbf{R^2}$ and sig. values concerning the drippers tested in the proposed operating pressure (1 ATM) for the determination of the features of the drippers were found as shown in Table 3.

Table 3. Dripper x, k, r, R2 and significance values.

Type of Dripper	x	k	r	R^2	Sig.
A	0.3897	0.6297	0.994	0.982	0.006**
B	0.3561	1.0807	0.997	0.991	0.003**
C	0.1567	0.7109	0.980	0.941	0.020*

According to the results of table 3, r values in the experiment came out between 0.980 and 0.997, which shows that the linear correlations between the pressure of all the drippers and the flow rate is very strong.

After inspecting the levels of importance, it is seen that the results of A and B types of drippers are very important ($P<0.01$) and the results of type C drippers are important ($P<0.05$).

When we look up the x coefficients in the table, all the drippers are classified as 'partial pressure stabilizer'.

Average flow rate amounts and standard deviation rates of the evaluated drippers in different pressures were given in Table 4. When the flow rate values under ideal operating pressures received from the producers and the values measured in the experiment are compared, type A differed 42% while type B and type C differed 6.75% and 21% respectively. As a result of these comparisons, the deviation in the type B drippers was observed low while the deviation in the type A and C were high.

Table 4. Average flow rate and standard deviation values of the drippers in different pressures that were used in the experiment (mL h-1)

Type of Dripper	Pressure (atm)			
	0.5	1.0	1.5	2.0
	$X \pm S_x$	$X \pm S_x$	$X \pm S_x$	$X \pm S_x$
A	225 ± 146.6	2841± 112.5	3447 ± 105.5	3995± 133.7
B	3466 ± 194.9	4274 ± 197.8	5100 ± 198.2	5917 ± 200.6
C	2162 ± 142.3	2426 ± 158.8	2618 ± 163.3	2737 ± 155.1

The connection between the flow rate and pressure for the dripper type A, B and C are modeled with linear regression and it was found out that the total variation of the data set of the model created were able to explain 99%, 100% and 95% respectively (Table 3). In other words, a positive correlation between the pressure and the flow rate was observed (Figure 1).

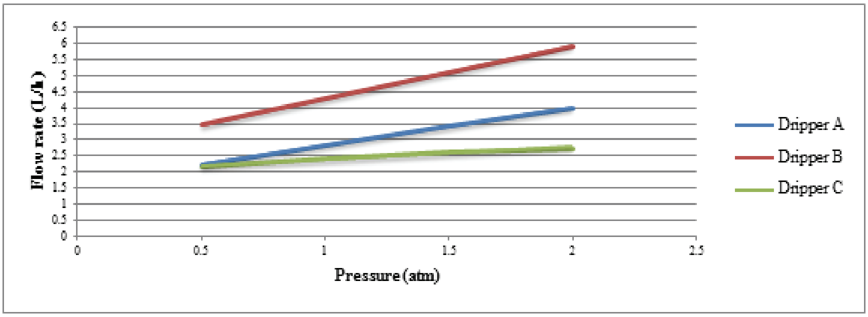

Figure 1. Flow rate - pressure correlations of the drippers used in the experiment

As Karmeli (1977), Von Bermuth and Solomon (1986) stated, the dripper type A, B and C increase in a complete logarithmic relation depending on the operating pressure (Kapar, 1991).

It can be observed in Figure 1 that the flow rates of the dripper type A and B increased together with the pressure, just as they were anticipated by the company as pressure unregulated. The dripper type C which is marketed as a pressure regulated unit did not totally conform marketed properties as pressure increase affected flow rate of this dripper too.

Table 5. CVm, Us and EU values of the drippers used in the experiment and their classification

Pressure (ATM)	Company								
	A			B			C		
	CVm Class	Us Class	EU Class	CVm Class	Us Class	EU Class	CVm Class	Us Class	EU Class
0.5	6.59 G	93.40 E	91.20 G-E	5.62 G	94.70 G-E	92.92 G-E	6.58 G	93.41 G-E	91.49 G-E
1	3.96 E	96.03 E	95.72 E	4.62 E	95.37 E	94.17 E	6.54 G	93.45 G-E	91.19 G-E
1.5	3.06 E	96.93 E	95.84 E	3.88 E	96.11 E	95.25 E	6.24 G	93.75 G-E	91.90 G-E
2	3.34 E	96.65 E	96.11 E	3.39 E	96.90 E	95.65 E	5.66 G	94.33 G-E	92.61 G-E

Bozkurt (1996) in his research ascertained that CVm values were changing jointly with the pressure, however the change rates of the pressure regulated drippers are more than the pressure unregulated ones. Similar results were attained in the experiments based upon this research (Table 5). While the ranges of CVm values in the pressure unregulated dripper type A and B were around 1%, the measurements of the pressure regulated type C dripper did not exceed 1% except those in 2 atm.

As it can be observed in the Table 5, CV values of the dripper type A and B classified as "excellent" is the indication of the fact that the drippers water application quantities are similar. As CVm values of the dripper type C remained under 5%, which is the ASAE standard, it was seen that the homogeneity of the dripper type C in terms of the manufacturing were not as high as dripper A and B and their homogeneity of water application were poor (Figure 2).

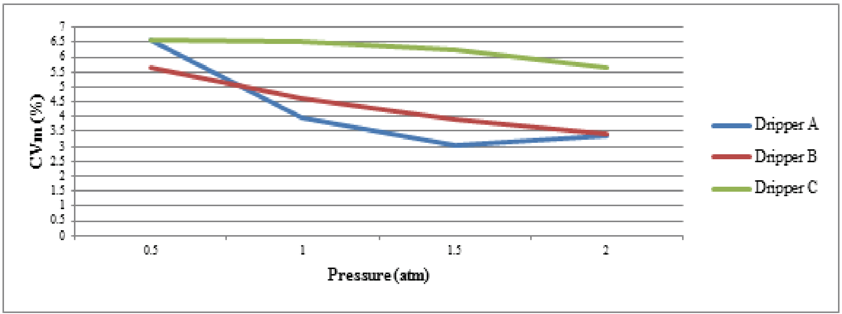

Figure 2. CVm-Pressure Relations of the drippers used in the experiment

The dripper type that had the highest Us value in accordance with the measurements conducted was the type A dripper, which also had the lowest CVm coefficient (1.5 ATM). Çamoğlu (2004) in his research tested 17 drippers under 1.0 ATM pressure and found out that the Us values of 65% of the in-line drippers remained over 95% while 67% of the in-line drippers in our experiments were over 95% (Figure 3).

While the EU values in the dripper A stabilized after 1 atm, an increase was observed in the dripper B together with the pressure. The EU value of the dripper C started to increase after 1 atm pressure. The highest EU value was observed in the type A dripper (Figure 4).

In accordance with the 95% Cu principle under 1.0 atm pressure as Wu and Gitlin (1974) states, the dripper type C was below this level while the dripper type A and B were over it. The results obtained from the experiment shows us that – as we take the loss of pressure and friction in the experiment were negligible – the difference of structural coefficients caused these values. In order to ensure Cu≥95% condition of the dripper B, it was deemed suitable to operate equal and over 1 atm pressures (Figure 5).

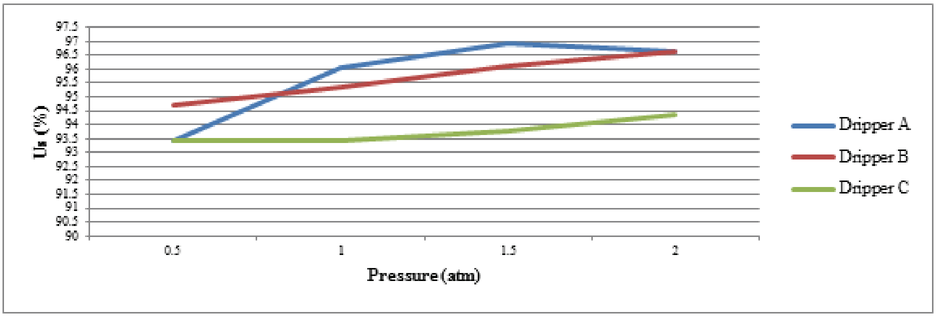

Figure 3. Us-Pressure Relations of the drippers used in the experiment

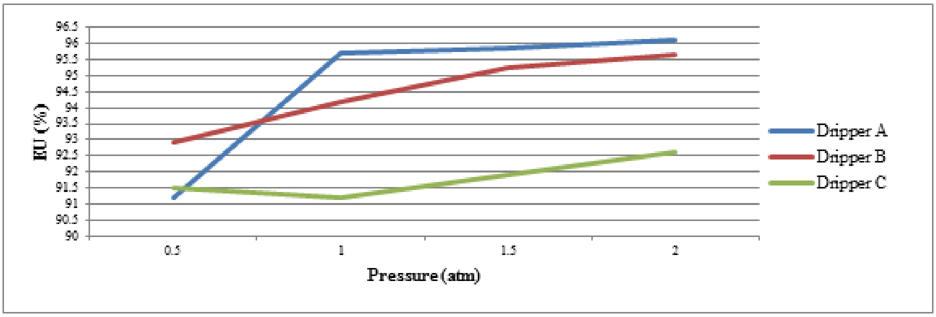

Figure 4. EU-Pressure Relations of the drippers used in the experiment

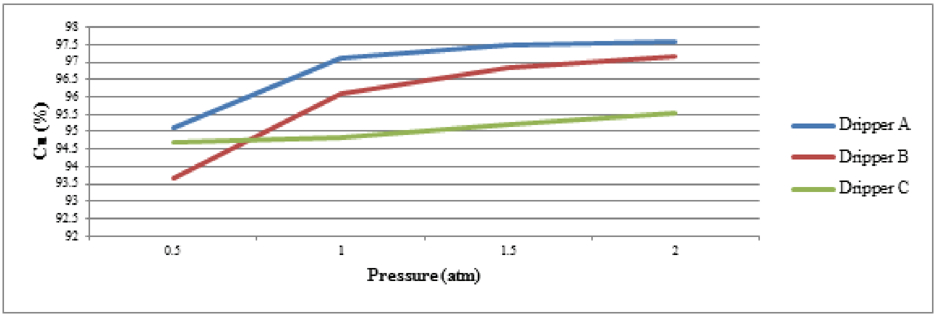

Figure 5. Cu-Pressure Relations of the drippers used in the experiment

CONCLUSIONS

When the flow rate values given by the companies and the values obtained at the end of the experiment are compared, the change in the in-line pressure regulated drippers is around 10%. When we analyzed the features of the dripper, obtaining the correlation coefficient values, shown as 'r', in all drippers between 0.980 and 0.997, indicates that the correlation between the pressure and the flow rate is very strong in every type of drippers. Different flow rates at the same pressure shows that drippers have an important effect on equal water distribution. Experiment results showed that the CVm coefficients of the in-line pressure regulated drippers are classified as 'good' while the in-line pressure unregulated drippers are classified as 'excellent' as they remained below 5% in terms of the proposed limits. Demir (1991) states that water leakage is caused between the dripper and the lateral pipe when the holes for drippers are not drilled carefully and thus the intended consistency level in the in-line drippers are not reached. The EU coefficients of the in-line drippers in our research were classified as 'excellent'. When the irrigation consistencies of the drippers are analyzed, the highest Us and EU coefficients were obtained in the in-line pressure unregulated drippers and therefore classified as 'excellent'. When the Cu coefficients were analyzed, the 95% limit that was mentioned by Wu and Gitlin (1974) were passed by the dripper A and B

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