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Effects of Drip Irrigation System Pressure Fluctuations on Drip Lateral Emitter Flow Rate and Diameter Change

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ABSTRACT

This study was conducted to determine the effects of drip irrigation system in line pressure fluctuations on drip lateral diameter expansion and emitter discharge rates. Pressure tests were carried out using ASAE test procedures with 6 different laterals with different physical characteristics from different manufacturers. Measurements were conducted using 3 replications of all laterals. Results showed that significant ($P<0.05$) swelling of drip irrigation laterals occurred due to pressure increases. However, there was no clear indication of drip lateral wall thickness effect on measurements swelling measurements. Results also indicated that changes in diameter at the maximum applied pressure ranged from 2 to 4%. Irrigation system pressure increases resulted in increased drip lateral emitter flow rates at statistically significant level ($P<0.05$) for all 6 brands used in this study.

Keywords: Pressure increase; Discharge; Lateral diameter; Wall thickness; Efficiency

Damla Sulama Sistemlerinde Basınc Değişimlerinin Damlatıcı Debisi ve Lateral Çapı Değişimine Etkisi

ESER BİLGİSİ

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ÖZET

Bu çalışmada, damla sulama sistemlerinde meydana gelen basınç artışının damlatıcı debisi ile lateral çapına etkisi araştırılmıştır. Çalışmada, ASAE standardına göre test protokolleri oluşturulmuş, 6 farklı üretici firma tarafından üretilen damla sulama lateralleri kullanılmış ve yapılan ölçümler 3 tekrarlı olarak gerçekleştirilmiştir. Deneme sonuçlarına göre; (a) üretici firmalar tarafından önerilen işletme basınçlarına ek olarak 25 kPa artırımlı 100.0 kPa'a kadar olan basınç değişimlerinde lateral çaplarında istatistiksel olarak önemli genişlemeler meydana gelebileceğini göstermiştir ($P<0.05$). Ancak farklı firmalar tarafından üretilen farklı et kalınlığındaki laterallerin etkisi saptanamamıştır. Ayrıca, uygulanan maksimum basınç artışları sonucunda lateral çaplarında % 2 ile 4 lük artışlar saptanmıştır. Diğer taraftan (b), sulama sisteminde meydana gelebilecek basınç artışlarının test edilen tüm 6 damlatıcı debilerinde önemli düzeyde ($P<0.05$) artışlar sağladığı hesaplanmıştır.

Anahtar sözcükler: Basınc artışı; Debi; Lateral çapı; Et kalınlığı; Etkinlik

1. Introduction

With new developments in agricultural, industrial and municipal industries, need of fresh water sources are increasing. Additionally, environmental concerns elevate competition for fresh water resources resulting in need for more efficient irrigation systems compared to traditional surface irrigation systems (Phene et al 1992). Compared to surface and sprinkler irrigation systems, drip irrigation systems have some advantages (Phene et al 1992; Bucks et al 1981; Lamm et al 1992; Dhuyvetter et al 1995) such as: (a) effective and efficient application of irrigation water to the crop root zone; (b) injection of chemicals and fertilizers through irrigation system (Bucks et al 1981); (c) adaptation to use in different topography (Lamm et al 1992; Dhuyandtter et al 1995; Wei et al 2003) and; (d) less risk of plant disease due to wetting of plant canopy. Karaca & Selenay (2001) reported that drip irrigation system used about 40% less irrigation water as compared to surface irrigation and also drip irrigation was economically favorable at/above 13 ha agricultural land under Harran Plain conditions. Similar results in favor of drip irrigation system were also reported Soydam & Cakmak (2006).

For an efficient irrigation, water has to be uniformly applied to the crop field. The emitter device is the main component of a drip irrigation lateral and determines the drip irrigation capacity. In order to have limited emitter discharge fluctuations, emitter exponent (x) has to be as low as possible (Yun-Kai et al 2006). Factors effecting uniformity are; changes in manufacturing process, change in system pressure, topography, clogging of emitters, and friction losses trough laterals (Solomon 1985; Mizyed & Kruse 1989). Mizyed & Kruse (1989) claimed that water application efficiency of drip irrigation systems is altered by system - emitter hydraulics, and system operation. Long drip lateral lengths in the large agricultural fields could also be a source of non-uniformity. Therefore, it is important to know the uniformity characteristics of drip irrigation laterals before they are applied to agricultural fields. Non-uniform irrigation results in less crop development and yield due to over and/or deficit irrigation at the top and

end of a given field (Wu 1997; Bhatnagar & Srivastava 2003). Uniform water application through drip irrigation systems could even be more important with fertilizer and chemical applications. However, the negative effect of non-uniform irrigations could be avoided with appropriately planned drip irrigation system (Decroix & Malaval 1985). Therefore, emitters play a crucial role on system performance (Al-Amount 1995).

Hence, the goal of this study was to evaluate the drip irrigation system pressure fluctuations on dripline' diameter expansion and emitter flow rates for 6 different products.

2. Material and Methods

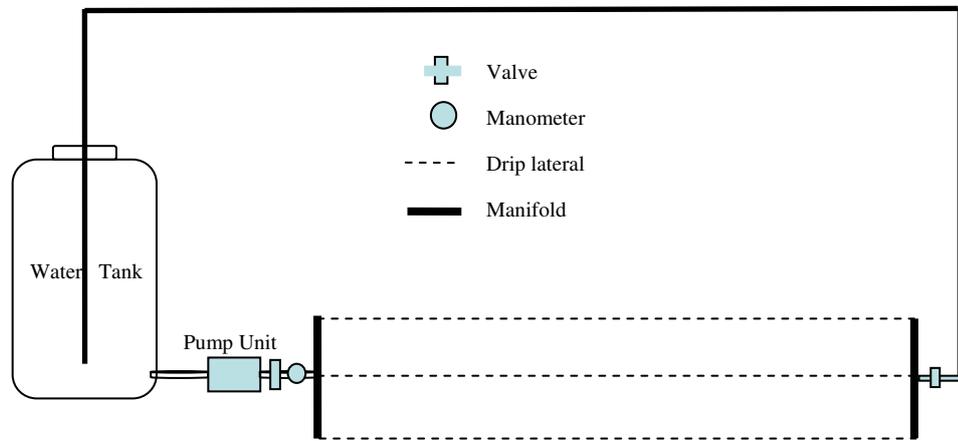
This study was conducted at the department of Irrigation Engineering hydraulic laboratory, Faculty of Agriculture, Harran University, Turkey. 6 commonly used non-pressure compensating drip irrigation laterals from different manufacturers were tested with 3 replications. Tested drip irrigation laterals' wall thickness ranged from 0.85 - 1.10 mm with all having 16 mm diameter. Emmitter spacing ranged from 250 mm to 750 mm with all emitters having a discharge rate of 4 l h^{-1} (Table 1). Drip laterals were cut at a length containing 5 emitters with three replications and connected to a manifold that was attached to an electrical water pump. Irrigation water used in the study was municipal tap water at a temperature around 25°C . Before measurements were taken, system was operated for 15 minutes to condition the laterals. During the tests, some of the water was also allowed to discharge in order to insure a constant pressure and simulate field conditions (Figure 1). After 15 minutes of conditioning, emitter flow rate measurements were carried out by measuring discharges from all 5 emitters on a single lateral length. Laterals were first tested at manufacturer suggested pressure (*MSP*) and then the same laterals were tested with pressure increments of 25 kPa up to a pressure increase of 100 kPa.

Drip irrigation laterals were elevated about 50 cm above the ground so that flow rate measurement could easily be carried out. Flow rates were collected with water collectors for 60 seconds and then weighed with an electronic balance with a 0.01

Table 1-General characteristics of drip irrigation laterals

Çizelge1- Çalışmada kullanılan damla laterallerin genel özellikleri

Drip lines brand	Wall thickness, mm	Emitter spacing, mm	Manufacturer reported discharge, $l s^{-1}$	Manufacturer reported external diameter, mm
A	0.90	250	4.0	16.0
B	0.85	750	4.0	16.0
C	0.90	750	4.0	16.0
D	1.10	250	4.0	16.0
E	0.90	330	4.0	16.0
F	0.85	750	4.0	16.0

**Figure 1-System set up used to test drip emitters**

Şekil 1-Damla laterallerinin testinde kullanılan sistem

g sensitivity and measurements were converted to $l s^{-1}$ unit. The water collectors used to catch the emitter discharge were dried after each measurement. The test data were analyzed with a regression analyses method in order to determine the emitter coefficients and exponents for all tested brands' laterals as given below (ASAE 2003):

$$q = K \times H^x \quad (1)$$

where: Q is discharge in $l s^{-1}$; K is emitter coefficient; H is system operating pressure in kPa; and x is emitter exponent.

Drip lateral diameter changes due to pressure increases were measured between first and second emitter at all pressures once at a water temperature of 25°C with a digital caliper with 0.1 mm sensitivity. Diameter changes were measured at the same pressure and temperature on 3 drip lines.

Both emitter discharge results and lateral

swelling data were analyzed using both ANOVA and regression analysis methods in order to determine if there was any difference among treatments and also to calculate equations representing the measured parameters. Also, the degree of significance for all tested laterals determined using the same statistical test procedures with SPSS (2002) computer based statistical program.

3. Results and Discussions

The emitter discharge rate measurements indicated that overall, drip emitter flow rates at manufacturer reported operating pressures were close to manufacturer reported emitter discharge rates. In general, the highest difference between measured and manufacturer reported values were close to 0.9 $l s^{-1}$. However the first two brands reported discharge rates were quite close to measured ones

with 0.1 l s^{-1} . With increase in irrigation system pressure, emitter flow rates also started to increase regardless of the brands. Flow rate changes due to pressure changes were no more than 21 and 32% for pressure increases of 25 and 50 kPa, respectively, and those pressure increases represent 25 and 50% of manufacturer suggested operating pressures.

In general, as system pressure increased, emitter discharge also increased regardless of brands. ANOVA analysis of the discharge rate measurements under different pressures indicated a significant ($P < 0.05$) increasing trend. Overall, emitter discharge rate measurements indicated that the change in flow rates were parallel to pressure increase. ANOVA and regression analyses of the flow rate data indicated that all regression equations

for all brands were significant ($P < 0.05$) and indicated that the determined coefficients could be used for the emitters (Tables 2, 3 and Figure 2). On the other hand, 100% pressure increase resulted up to 50% discharge increase but overall was less than 40% for the tested laterals (Table 2). Similar to current study results, a strong relationship between drip irrigation system pressure and emitter flow rate was reported by researchers (Ozekici & Sneed 1995; Kirnak et al 2004; Clark et al 2005; Camoglu and Yavuz 2006). Regression analyses of the pressure tests results indicated that emitter flow rate equations ($q = K \times H^x$) had emitter coefficients (K) of 0.45, 0.49, 0.49, 0.38, 0.34, and 0.41, whereas emitter exponent values were 0.45, 0.48, 0.49, 0.53, 0.55, and 0.50 for A, B, C, D, E, and F manufacturer laterals, respectively.

Table 2-Test results of drip irrigation laterals for lateral diameter to emitter discharge

Çizelge 2-Damla lateralleri çap ve damlatıcı debi değişim sonuçları

Drip lines brand	Lateral diameter swelling, %	Min. flow rate, l s^{-1}	Max. flow rate, l s^{-1}	Flow rate increase, %	Emitter coefficient, K	Emitter exponent, x
A	1.49	4.1	5.2	26.8	0.45	0.45
B	2.53	4.1	7.3	52.1	0.49	0.48
C	1.88	4.9	6.5	32.7	0.49	0.49
D	2.85	4.4	6.0	36.4	0.38	0.53
E	2.01	4.6	6.0	30.4	0.34	0.55
F	4.16	4.7	6.5	38.3	0.41	0.50

Table 3-Lateral diameter to emitter discharge changes at tested pressure and statistical analysis results

Çizelge 3-Basınç artışlarına bağlı lateral çapı, damlatıcı debi değişimleri ve istatistik sonuçları

Drip lines brand	Pressure, kPa							SEM	P value
	Flow Rate, l s^{-1}								
	100	125	150	175	200	225	250		
A	3.8a	3.8ab	4.0bc	4.7cd	5.2d			0.28	0.015
B	4.1a	5.0ab	5.5bc	5.6c	7.3d			0.43	0.006
C	4.9a	5.3ab	5.6b	5.9bc	6.5d			0.31	0.018
D	4.4a	4.9ab	5.2b	5.4bc	6.0d			0.48	0.053
E	4.6a	4.8a	5.2b	5.6c	6.0d			0.36	0.102
F			4.7a	5.6b	5.8bc	6.0c	6.5d	0.62	0.001
	Swelling, %								
A	0.00a	0.06a	0.44b	0.68bc	1.49d			0.07	0.014
B	0.00a	0.52b	0.78bc	2.21d	2.53b			0.12	0.015
C	0.00a	0.94b	1.41c	1.41c	1.88d			0.08	0.002
D	0.00a	0.07a	0.60b	0.73bc	2.85d			0.22	0.003
E	0.00a	1.67b	1.74bc	1.80c	2.01d			0.24	0.001
F			0.00a	1.50b	2.28c	2.86c	4.16d	0.26	0.009

Values at the same row followed by different letters are significantly different at $P < 0.05$ level

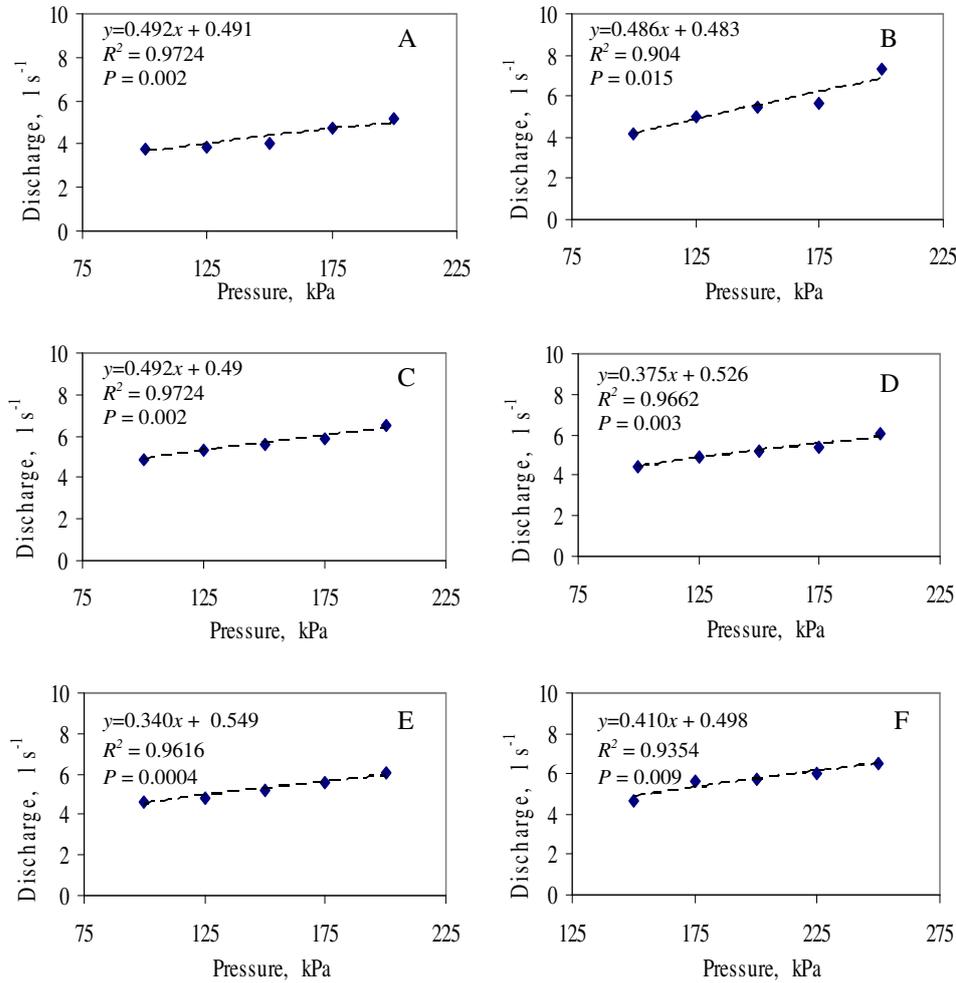


Figure 2-Relationship between system pressure and drip lateral diameter change of tested drip laterals manufactured by A, B, C, D, E, and F companies

Şekil 2-Çalışmada kullanılan A, B, C, D, E ve F firmalarına ait laterallerde basınç değişimlerine bağlı çap değişimleri

Even small changes in emitter exponents show that weakness of the emitter to pressure resulting in big variation in flow rate. Regression coefficients (R^2) for the equations were 0.93, 0.94, 0.98, 0.98, 0.96, and 0.98 for the respective laterals (Table 2). Since lower emitter exponents are indication of less susceptibility to pressure changes, emitters could be ranked as A, B, C, D, E, and F with an increasing trend. Similar results were also reported by Ozekici & Bozkurt (1996).

Drip irrigation lateral expansion ranged from 1.49 to 4.16% at maximum pressure increase

(100%). Generally, one might expect that wall thickness of a lateral play a role on diameter expansion, however there was no indication of that in our measurements (Table 3). The reason could be attributed to the pressures used in the study, which were not high enough to see the effect of the wall thickness on measurements. Up to 50 kPa (50%) pressure increase, lateral diameters were slightly affected and the effect was limited to 2% and most of the time was less than 1%. Swelling measurements in general indicated a significant ($P<0.05$) changes in lateral diameter in all

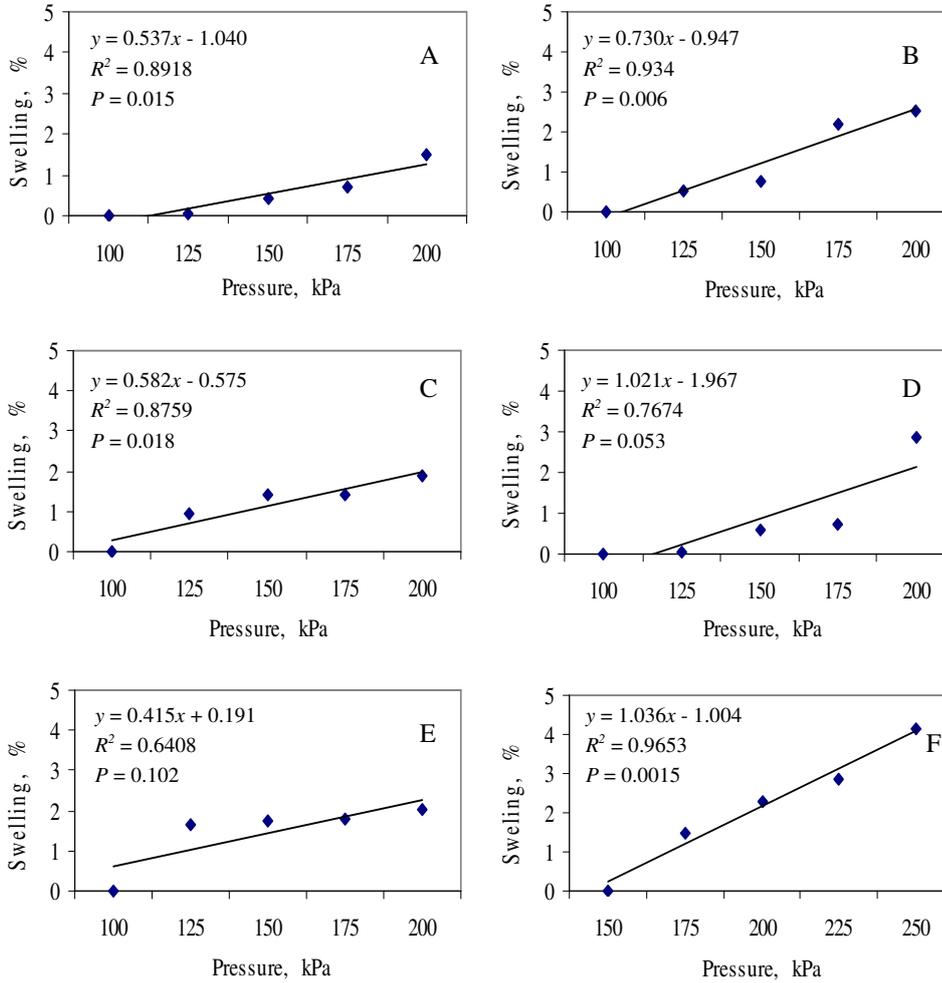


Figure 3-Relationship between system pressure and drip lateral emitter flow rates of tested drip laterals manufactured by A, B, C, D, E, and F companies

Şekil 2-Çalışmada kullanılan A, B, C, D, E ve F firmalarına ait damlatıcılarda basınç değişimleri ve debi değişim ilişkileri

diameters. However, with small pressure increases this significant difference was not obvious in all brands (Table 3 & Figure 3). Expansion of lateral diameters will certainly affect the hydraulic characteristics of drip line and possible interfering with overall performance of emitters.

4. Conclusions

In general, the effect of pressure increase resulted in increased swelling of the drip laterals and it was

statistically significant ($P < 0.05$) for all tested materials. Lateral swellings for the maximum pressure did not exceed 5%. In general it was limited to 3%. Wall thickness of the laterals seemed not to be a factor affecting the swelling of the laterals. Significant diameter change (increase) could also reduce friction loss and affect emitter flow rates. An increase in irrigation system pressure resulted in increased emitter flow rates limited to 10%. However, the changes were even lesser in some of the brands compared to others.

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